COMMUNICATIONS SYSTEMS PERFORMANCE GUIDE
FOR
PROTECTIVE RELAYING APPLICATIONS
November 21, 2001

This guide was prepared jointly by the WSCC Telecommunications and Relay Work Groups.

1.0 Purpose

The purpose of this guide is to provide communications system designers with basic performance criteria required for communication circuits carrying protective relaying traffic. It is not a detailed design specification. The need for this guide was precipitated by the recognition of potential relay timing problems arising from the application of digital communications and switching technologies. However, since these performance standards are functional they apply to analog, digital or hybrid systems.

2.0 General Comments

2.1 Reliability

The definition of reliability developed by the Relay Work Group reads as follows:

> Reliability of protective relay systems can be divided into two areas: **Dependability and Security**.
>
> **Dependability** The facet of reliability that relates to the assurance that a relay or relay system will respond to faults or conditions within its intended zone of protection or operation.
>
> **Security** The facet of reliability that relates to the assurance that a relay or relay system will restrain from faults or conditions outside of its intended zone of protection or operation.
>
> Two different failure modes are considered: failure to operate and unnecessary operation. All elements in the protective system are considered, including relays, CT's, PT's, communication channels, all supply and control wiring, and station batteries. The only element not considered a part of the protection system is the mechanical malfunction of a power circuit breaker.
>
> **Failure to Operate** is defined as a failure of a terminal, including the relay system and power circuit breaker, to clear a fault when it should.
>
> **Unnecessary Operations** of a relay scheme are classified into two groups:
>
> A. Unnecessary operation in a non-fault condition.
>
> B. Unnecessary operation due to a fault occurring outside of its primary protection zone, (i.e. external fault).

Relay security may also include the ability of a relay or relay system to restrain from operation for an external fault on an adjacent line, transformer, bus, or a component that is several busses removed in some cases. An example of this would be a transmission line pilot communications protection scheme with highly sensitive, overreaching ground overcurrent elements used for start/stop of the pilot communication channel. Some protective relays may misoperate during loss of a relay communication during normal load conditions. All protection schemes should be designed to be tolerant of channel failure conditions.

The definition of protection reliability includes communication channels as part of the protection system. Therefore, communication channels are considered to include all communications equipment required to deliver information from an initiating relay at one location to a receiving relay at another location. For purposes of this guide, reliability of the communications system is therefore a measure of overall reliability. It should be noted that this is not the same measure of reliability or availability as used in path designs.

This definition also highlights the concept that security is an important component of reliability. Security should therefore be an important criterion in the design of communication circuits for relay applications.

2.2 Communications System "End-to-End" Definition

Given that communications channels are defined as in Section 2.1, then the phrase "End-to-End" is taken to mean from the initiating relay to the receiving relay as shown in Figure 1, below. The diagram below is not intended to present the traditional protection systems where all End-to-End communications are external to the protective relay. It includes the newer digital relays that have the ability to initiate and receive the

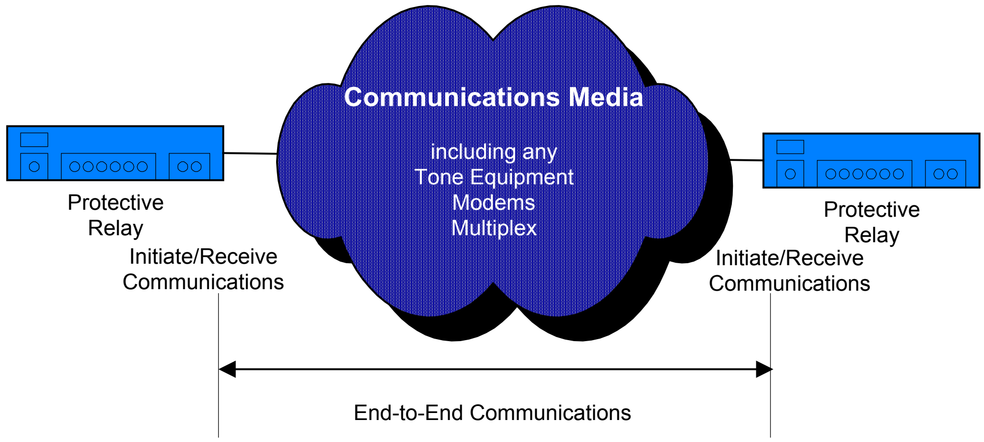

Figure 1. End-to-End Communications Definition

communication signals. Any protective relay delay in processing the communications signal must be accounted for to satisfy the performance specified in Timing Requirements Table, presented later in this document. To make use of this definition; End-to-End delay is the total time delay from the output of the initiating relay to the input of the receiving relay. This delay includes any data buffering associated with digital multiplex. For example, an End-to-End delay of one cycle (16.67 ms) would be the sum of all the equipment and propagation delays existing between the two relays.

2.3 Availability

The communications portion of the protection system must provide a level of availability consistent with the protective relay equipment. Thus availability is total time less unavailability time for all components or support system needed to effect the end-to-end communications linkages divided by the total time in the period measured. Unavailable time will include the communications power systems, hardware outages, radio path fades (if radios are utilized), fiber breaks (which contribute to an outage), software outages and procedural outages (workman error).

Several industry papers have presented discussions on the expected availability of protective relays. The availability is presented as "Protection Unavailability" and "Abnormal Unavailability."

> "Protection Unavailability" is defined as the period of time a protective relay is unavailable due to failure and testing and is dependent on its Mean Time Between Failure, MTBF (or Mean Time To Failure, MTTF) and testing interval.
>
> "Abnormal Unavailability" measures the protection unavailability during a power system element fault.

The Unavailability term can be converted to the communications standard availability term by subtracting unavailability from 1 and converting to percent. The industry papers present Protection Unavailability at 9.4×10^{-2} for standard relays and 1×10^{-4} for relays with self-testing features. These two numbers equate to 90.6 and 99.99 % availability.

It is essential that the communications systems be designed to operate during transmission impairments that are likely to occur coincident with power system faults. Refer to the WSCC Telecommunications Work Group Design Guidelines for Critical Communications Circuits.

2.4 Resynchronization

The two ends of a digital communication system employed to carry protective relay traffic will operate in synchronism. Any communication transmission equipment drop out will result in a need to resynchronize prior to transmission of the communications traffic. The Bellcore standard for SONET requires multiplex equipment resynchronization within 60 ms. Additionally, Bellcore standard TR-TSY-000752 specifies digital microwave to resynchronize in 100 ms on average. Manufacturers typically specify resynchronization times of 100 ms for SONET digital microwave and fiber optic equipment, 50 to 300 ms for asynchronous microwave radios, and less than 50 ms for digital channel banks. Channel drop out should not occur coincidentally with a power system element fault when a communications system is properly designed. A proper design would include particular attention to communications equipment grounding at power stations. Therefore, resynchronization should not be an issue for the use of digital communications systems.

2.5 WSCC/NERC Criteria

In addition to the recommendations in this guide, communication system designs must meet all applicable WSCC Minimum Operating Reliability Criteria (Section 7) and NERC Planning Standards. [2,3,4] This applies to all facilities under WSCC jurisdiction, generally described as bulk transmission facilities.

3.0 Performance Levels

The digital communications performance requirements, which are of concern for protection schemes, are maximum End-to-End delay, variable End-to-End delay, unequal End-to-End delay, availability and redundancy. The three delay concerns are differentiated by the applied protection scheme such as direct transfer trip or phase comparison. Where as, the availability is dependent on whether the scheme is protecting a transmission line or RAS system. Finally, redundancy is required when failure of the protection system will result in violation of the applicable NERC Planning Standards and WSCC Criteria.

3.1 Table Definitions

3.1-1 Protection Scheme

Two State Scheme: Protection schemes whose input to the communication system represents either of two logic conditions (e.g. on/off for DCB, guard/trip for POTT, etc.). There is no analog or encoded data.

Encoded Data: Protection schemes whose input to the communications system represents some type of time sensitive, encoded information (e.g. phase comparison, current differential).

3.1-2 Application

Type of relay protection scheme:

Table Name	Application Name	Description
Direct TT	Direct Transfer Trip	Direct circuit breaker tripping upon receipt of remote trip signal via communications
Permissive	Permissive Overreaching Transfer Trip (POTT), Permissive Underreaching Transfer Trip (PUTT)	Circuit breaker tripping is qualified by both local fault detection and receipt of remote trip signal via communications
Blocking	Directional Comparison Blocking (DCB) Directional Comparison Unblocking (DCU)	Circuit breaker tripping is qualified by both local fault detection and no receipt of remote block signal via communications

Table Name	Application Name	Description
Phase Comparison	Phase Comparison	Circuit breaker tripping is based on coincidence of local and remote waveforms representative of phase current
Current Differential	Current Differential	Circuit breaker tripping is based on coincidence of local and remote phase current waveforms
RAS	Remedial Action Scheme, Special Protection Scheme	Each Remedial Action Scheme is configured to its specific application and cannot be generally described

3.1-3 Maximum End-to-End Delay (Typical)

This is the maximum allowable time delay to meet line-clearing requirements. It is measured from the output of the initiating relay to the input of the receiving relay. This delay includes any data buffering associated with digital multiplex. The maximum End-to-End delay for any protection scheme is dependent on the power system stability requirements. The protection engineer should provide the maximum End-to-End delay allowable for the communications channel. Any actual End-to-End delay that differs from the values presented in Table 1 should be accounted for through adjustment of applicable protection scheme settings.

3.1-4 Variable End-to-End Delay Permitted

A changing End-to-End Delay resulting from communications path switching.

Up to Maximum – the End-to-End delay may vary from zero up to the maximum End-to-End delay.

Relay or Scheme Dependent – End-to-End delay may not vary beyond relay or scheme tolerance.

Solid-state encoded protective relays may be intolerant of variations in End-to-End delay. Such variations in delay result in protective relay misoperation. Some modern microprocessor relays employ a digital messaging system that determines the End-to-End delay while transmitting the data between the relays. These relays block relay operation on channel drop out and do not restore operation until the delay is determined. They are tolerant of variations in delay but not tolerant of unequal End-to-End delays discussed below.

3.1-5 Unequal End-to-End Delay Allowed

A terminal’s transmit End-to-End delay differs from its receive End-to-End delay.

Up to Maximum– the End-to-End delay in one direction may differ from the other direction up to the maximum End-to-End delay.

Relay or Scheme Dependent – the relay measures the loop delay, assumes the End-to-End delay in one direction is half of the total and applies this value to align encoded data.

Some modern microprocessor relays employ a digital messaging system that determines the End-to-End delay while transmitting the data between the relays. These relays block relay operation on channel drop out and do not restore operation until the delay is determined. Many of these relays assume the End-to-End delay to be half of the measured loop delay. These relays attempt to align the remote terminal data to the local data with half the measured delay. An unequal End-to-End delay may result in relay misoperation.

3.1-6 Class

The class of transmission line:

Class	Description
1	A bulk power transmission line or RAS requiring totally redundant protection systems to comply with applicable NERC and WSCC Planning Standards.
2	A bulk power transmission line or RAS that does not require totally redundant protection systems to comply with the NERC Planning Standard.
3	A non - bulk power transmission line that may require communications aided protection to satisfy power quality or other requirements of a given utility or customer.

3.1-7 "End-to-end" Functional Availability

The functional availability is related to the overall reliability required for the communication and protection system, reference sections 2.1 and 2.3. This includes all the communication and control systems elements between the end points. The application of redundant equipment or alternate routing of the communication signals will increase the "end-to-end" functional availability. Where a redundant communication system is required by NERC, the required minimum availability value is for the combined, redundant system. Scheduled maintenance is excluded from the availability calculation or measurement. The availability listed in Table 2 is the minimum availability required. Refer to the WSCC Telecommunications Work Group Design Guidelines for Critical Communications Circuits.

3.1-8 Redundancy

The operating criteria for redundancy are given in the applicable NERC and WSCC Planning Standards. Equipment redundancy refers to the active opto-electronic and/or radio shelves, multiplex, Transfer Trip, relay and power supply equipment providing the communication & control functional TT operation. Redundancy may also be used to increase the availability. Refer to the WSCC Telecommunications Work Group Design Guidelines for Critical Communications Circuits.

3.1-9 Alternate Routing to Meet the Specified Availability

Alternate routing of the communication signals may be required to provide the specified availability, the communication system configuration would then be designed so that no creditable single failure will cause loss of the communication, control and protection function(s).

3.1-10 Procedural Outage

These are outages caused by procedural errors. Each outage would typically be of short duration. However, there are many people working which could cause these procedural outages. The procedural outage is the sum of the individual events. Procedural outages are included in the availability requirements of Table 2.

3.1-11 Software Outage

The addition of communication, control and protection equipment that are dependent upon software is the source for these outages. This outage would include software "bug's" which are imbedded in the operational software/firmware that were not found during the pre-qualification or commissioning tests. The software outage total is the sum of individual outages. Software outages are included in the availability requirements of Table 2.

3.2 Performance Tables

Table 1
Timing Requirements

Protection Scheme	Application	Maximum End-to-End Delay (Typical)	Variable End-to-End Delay Permitted	Unequal End-to-End Delay Allowed
Two State	Direct TT	1 cycle @ 60 Hz, 16.67 ms	Up to Maximum	Up to Maximum
	Permissive	1 cycle @ 60 Hz, 16.67 ms	Up to Maximum	Up to Maximum
	Blocking	1/4 cycle @ 60 Hz, 4 ms	Up to Maximum	Up to Maximum
	RAS	1 cycle @ 60 Hz, 16.67 ms	Scheme Dependent	Scheme Dependent
Encoded Data	Phase Comparison	1 cycle @ 60 Hz, 16.67 ms	Relay Dependent	Relay Dependent
	Current Differential	1 cycle @ 60 Hz, 16.67 ms	Relay Dependent	Relay Dependent
	RAS	1 cycle @ 60 Hz, 16.67 ms	Scheme Dependent	Scheme Dependent

Table 2
Functional Availability and Redundancy Requirements

Class	Circuit Application	Minimum End-to-End Functional Availability
1	A bulk power transmission line or RAS requiring totally redundant protection systems	99.95% 265 outage minutes per year One 24-hour outage every 5.4 years
2	A bulk power transmission line or RAS not requiring totally redundant communication and protection systems	99.5% 44.8 outage hours per year Redundancy may be used to achieve this availability
3	A non - bulk power transmission line that may require communications protection to satisfy power quality or other requirements of a given utility or customer	95% 438 outage hours per year Redundancy may be used to achieve this availability

4.0 NERC Planning Standards III.A

The 1997 NERC Planning Standards section III A., System Protection and Control - Transmission Protection Systems, contains two Guides pertaining to communications systems used for protective relaying. The term Guides are defined in the NERC Planning Standards to be "Good planning practices and considerations that may vary for local conditions."[2] These guides address considerations for communications channel testing, monitoring and redundancy.

5.0 References

[1] J.J. Kumm, M.S. Weber, E.O. Schweitzer, D. Hou, “Assessing the Effectiveness of Self-Tests and Other Monitoring Means in Protective Relays”, Western Protective Relay Conference, October 1994.

[2] North American Electric Reliability Council Engineering Committee, “NERC Planning Standards”, September 1997.

[3] Western Systems Coordinating Council, “Proposed Reliability Management System (RMS)”, FERC Declaratory Filing, July 23, 1998.

[4] Western Systems Coordinating Council, “Reliability Criteria for Transmission System Planning”, March 1999.

[5] Western Systems Coordinating Council Telecommunications Work Group, “WSCC Telecommunications Work Group Design Guidelines for Critical Communications Circuits”, presently under development.