



EHV Transmission Line Protection White Paper

Relay Work Group

December 9, 2021

Table of Contents

Introduction	3
Relay Type	3
System Parameters.....	3
Fault Detection Capability.....	4
Trip Output Time	4
Local Breaker Failure	5
Security Requirements	5
Dependability Requirements.....	5
Maintenance Testing Provisions	6
Model Power System	6
Operating Temperature Range	7
DC Supply Voltages.....	7
Component Quality and Design Margins	7
Other Considerations.....	7
Version History.....	8



Introduction

The purpose of this white paper is to aid WECC members (Specifier) in specifying and applying relay systems that will provide adequate protection of extra-high voltage (EHV) on 345-kV or higher transmission lines and comply with the NERC Reliability Standards. The recommendations in this white paper are the result of experience of members of the WECC Relay Work Group in trying to obtain dependable and secure protective relay equipment for use on systems that include heavily loaded long lines, series capacitors, and shunt reactors.

This white paper does not constitute a complete specification, as there are many areas that depend only on user preference and requirements. These areas are listed for reference in the section titled Other Considerations. The white paper covers in detail only those areas that are critical in obtaining reliable equipment. While each utility specification will be different, this white paper will allow a utility to avoid some of the pitfalls that other users have encountered.

This white paper is intended for use when specifying new systems used on new EHV transmission lines or replacement of existing protection systems. It is not meant to force the retirement of existing systems that do not meet this white paper's recommendations. Although this white paper is written for whenever EHV primary line relay systems are being considered, it may be applied at lower voltages.

Relay Type

Utility standard is to specify digital (microprocessor-based) relays for new installations, or when a relay is to be replaced or upgraded. Modern digital relays are multi-function, flexible, able to support custom designed logic schemes, and have integrated features such as oscillographic event reporting and fault location.

System Parameters

Many system details must be considered when specifying the system to protect the EHV line, whether overhead or underground cable. This data should include line transpositions, line configuration (including overhead ground wires, shunt capacitance, self- and mutual-sequence impedances), voltage transformation device type and location, current transformer ratio and accuracy class, series capacitor locations and ratings, and shunt reactor location and ratings. Unusual operating modes of series capacitors, shunt reactors, point-on-wave controlled switching applications, and any other mode that may cause unbalance should be considered. In addition, source impedance ranges and line loading ranges should be specified and data on nearby series capacitors should be given.



Fault Detection Capability

The relay system should detect, and operate reliably for single line-to-ground faults, double line-to-ground faults, line-to-line faults, three phase faults, line-to-ground faults with an open conductor on one side, circuit to circuit faults (cross-country faults), all previous fault types with resistance, and all combinations of evolving faults which may include a transition from external to internal. Fault resistance is to be user specified based on the Specifiers expected line construction and soil conditions. Ground faults are usually the limiting case.

The relay should be capable of displaying the faulted phases and relay elements that operated to initiate tripping. Other information as well as targets may also be available through communication with microprocessor relays. The utility needs to determine the maximum contact and ground resistance through which its relay systems must operate correctly. A relay manufacturer and model must be selected to operate over the desired range, and if there are device-imposed limitations then the utility should consider developing a custom-designed solution to account for the difference.

The relay system should provide the above fault detecting capabilities in the presence or absence of internal series capacitors and shunt reactors with series capacitor Metal Oxide Varistor (MOV) conduction or gaps flashing, not flashing, or flashing unsymmetrically.

The relay system should provide the above fault detecting and operating capabilities in the presence of the Surge Withstand Capability Test described in ANSI C37.90.1-2012.

Trip Output Time

The Specifier will determine the maximum relay trip time necessary to maintain compliance with both intercompany-derived performance requirements and NERC Mandatory Reliability Standards. Communication with system planners and interconnected utilities may be necessary to determine those maximum acceptable times. The manufacturer should state in its proposal if local direct trip and/or communication-aided tripping is required to obtain the required trip output times and should identify the conditions under which direct trip and/or communication-aided tripping is required.

Communication channels that are required for the system to comply with NERC Reliability Standards should follow the recommendations in the Communication System Performance Guide for Electrical Protection Systems. Such communications channels should be continuously monitored or routinely tested. Routine testing may be automatically initiated and controlled or be done manually based on periodic scheduling.



Local Breaker Failure

The breaker failure relaying should be designed to remove the minimum number of elements necessary to clear faults. Breaker failure relaying is not required to be redundant, but a breaker failure relay should not be initiated from the same auxiliary relay that is used to trip the breaker. With multi-function microprocessor-based relays being the modern standard choice, utilities may choose to implement redundant breaker failure relaying at a minimal incremental cost.

Security Requirements

Relay systems should be designed to isolate only the faulted electric system element(s). The relay system should be secure from false operation for external faults in the presence or absence of external and internal series capacitors with any series capacitor MOV conduction or gaps flashing, not flashing, flashing unsymmetrically, or reinserting unsymmetrically.

The relay system should be secure from false operation during line energizing in the presence or absence of internal shunt reactors and transformers and during the switching of internal shunt reactors and transformers.

The relay system should be secure from false operation during switching or loss of the DC supply.

Depending on the type of relay system used, consideration should be given to relay system performance during:

1. Power swings;
2. Emergency loading conditions as prescribed by NERC Reliability Standards addressing loadability; and/or
3. Any credible contingency including sustained depressed voltages; and/or
4. Automatic reclosing or single-pole switching of EHV transmission lines where studies indicate enhanced system stability margins are necessary or at the discretion of the Specifier.

The Specifier should consider requirements for security during loss of AC potential caused by a blown potential fuse, tripped circuit breaker, or potential source switching.

The relay system should be secure from false operation in the presence of the ANSI C37.90.1-2012 Surge Withstand Capability Test.

Dependability Requirements

At least two relay systems are required to achieve dependability for EHV transmission line protection based on applicable NERC Reliability Standards. Each system should operate from separate AC current



and potential secondary windings, have separately protected DC control voltages, and should have dual circuit breaker trip coils operated by separately protected DC sources. The EHV transmission line protection should be designed to eliminate the possibility that a single Protection System component failure can disable all applied systems.

For Protection Systems that use telecommunications, such as line current differential or permissive over-/under-reaching transfer trip schemes, a communications-independent protection function must be designed into the System to ensure dependability in the event of communications failure. Where telecommunications is used to achieve a performance (speed) requirement, it should be noted that the communication independent function is not expected to meet that same requirement.

Breaker failure protection need not be duplicated. However, if the breaker failure functionality is included as part of a multifunction relay, the breaker failure function should be included in at least two of the multifunction relays used to meet the dependability requirements.

Maintenance Testing Provisions

All systems should have provisions for testing and calibration of all relay elements. All systems should have the capability to isolate AC current and voltage inputs, tripping contacts and other contact outputs. Input sensors should also have isolation capability to perform testing and maintenance.

Systems using a rotary cutout switch to disable relaying, such as breaker failure or bus differential protection, should provide an alarm whenever the relaying is disabled by that cutout switch.

The relay systems and associated maintenance procedures should be designed to minimize the likelihood of personnel error during testing, such as incorrect tripping or inadvertent disabling. The systems should be functionally tested when initially placed in service and when modifications have been made to verify the dependability and the security aspects of the design.

Model Power System

The Specifier may request that a relay system's desired performance be verified by model power system testing. The proposed model must satisfactorily represent the Specifier's power system. The Specifier has the option to require a test of one complete system of a multiple order, accept the test of a previous system, or test every system.

Regardless of whether model power system testing is performed, the Specifier must also prepare a procedure for commission testing of the relay. An applications-based test procedure is the recommended approach for commission testing.



Operating Temperature Range

The relay system should neither trip falsely nor fail to trip when the ambient temperature is in the range -20°C to +55°C. Temperatures in this range should cause neither component failure nor excessive component aging.

DC Supply Voltages

The relay system should be designed to use separate protected DC circuits; one for power supply/logic and one for each tripping circuit. The relay system should be subject to the same voltage limitations as circuit breaker tripping functions. Battery voltage equalization practice should be considered when specifying the upper limit. An alarm contact for loss of the DC power supply/logic should be provided.

Component Quality and Design Margins

The objective of this white paper is to obtain a dependable and secure relaying system. The equipment proposed should be of high quality in design, component selection, and workmanship equal to the value and importance of the power system it will protect. Careful selection and testing of components and assembled devices should be considered.

Components:

- The manufacturer should be responsible for selecting components so that the relay system will meet the functional and environmental requirements with sufficient margin to provide satisfactory operation during the expected life of the relay system. The manufacturer should state the design life of the equipment in its proposal.
- The Specifier should consider the possibility of common-mode failure among relays and communication facilities, brought on by either similar operating principles or components.

Other Considerations

In addition to the items covered above, there are many that depend on user requirements. They are listed here for reference:

- Instruction books
- Technical support availability
- Training of personnel
- Cost of initial design and implementation



Disclaimer

WECC receives data used in its analyses from a wide variety of sources. WECC strives to source its data from reliable entities and undertakes reasonable efforts to validate the accuracy of the data used. WECC believes the data contained herein and used in its analyses is accurate and reliable. However, WECC disclaims any and all representations, guarantees, warranties, and liability for the information contained herein and any use thereof. Persons who use and rely on the information contained herein do so at their own risk.

Version History

Modified Date	Modified By	Description
RWG	June 6, 2006	
OC	June 18, 2009	
	March 9, 2011	Reformatted Document
RWG	November 19, 2015	Reviewed and Modified Document
TOS	January 6, 2016	Recommends OC Approval of Document
OC	July 12, 2016	Approval of Document
RWG	December 9, 2021	Expanded Content, Reformatted in new WECC Template
EPAS	September 7, 2022	EPAS Approval, Recommends RRC Approval of Document
RRC	October 20, 2022	RRC Approved Document

