

PJM Requirements for End to End Line Protection Testing

Purpose

This document details the requirements for performing end to end testing of each participating PJM Company when commissioning, modifying or troubleshooting interconnected line protection schemes.

Scope

This document applies to all PJM interconnected line protection schemes. This document may also serve to provide guidance to any PJM company's intra-connected line protection schemes.

Background

The use of dynamic state end to end testing among electric utilities has become an accepted method to best predict the actual real time performance of line protection schemes. This testing method is typically applied in addition to any, and all, traditional terminal testing such as input/output testing, relay testing and functional testing employed by individual utilities. Because the routine use of end to end testing is so common among nearly all domestic utilities and often a requirement of placing the scheme in service, it is imperative that a documented protocol be established and act as a condition of understanding between all participating PJM utilities.

Definitions

Steady State Testing: Applying current and voltage quantities to the protective relay to determine the operating point. The applied quantities are slowly and gradually changed to cause relay operation.

Automated (Computer Based) Testing: Use of a computer and test equipment software to test relay elements, settings and logic. The software controls the test equipment, and generates a test report for documentation purposes. Computer

based testing improves speed, accuracy, and repeatability by supplying a faster and more controlled change in current and voltage quantities.¹

Dynamic State Testing: Is automated testing that applies a series of voltage and/or current quantities that transition from pre-fault, to fault and post fault states. The waveforms are typically free from transient signals.

Fault Record Testing: Is automated testing that applies recorded fault current and voltage quantities to the protective relay. This testing simulates actual system voltages and currents during normal load and fault conditions by “playing back” transient files recorded during actual system load and fault events.

End to End Testing: Automated dynamic state testing that simultaneously applies GPS time synchronized current and voltage quantities to all terminals of a circuit. This method is applied to protection and control systems which utilize communications to facilitate operation. This testing is especially valuable in the case of dissimilar relay manufacturers or different eras of protection system design.² (See appendix A for an example of an end to end test plan)

Commissioning Tests: Commissioning tests are used when placing new or modified protection and control systems in service. Modifications significant enough to warrant commissioning tests may include; various setting changes, timer changes, firmware upgrades, communications changes or extensive wiring modifications.

Prerequisite Local Testing

The testing methods described below should be applied at the terminal end where modifications have occurred prior to performing end-to-end testing. The tests requiring coordination between remote terminals such as end to end testing

¹ To facilitate Automated Tests, new panel designs should incorporate access to inject test signals and connect test equipment to inputs and outputs of relays.

² Conventional electromechanical schemes did not include provisions for testing relaying in place as a system. Access to monitoring points, higher burdens and lack of isolating points create hurdles for successful end to end testing. Temporary modifications may be necessary to facilitate this testing. Upon completion of testing, restoration of modifications should be verified to ensure proper functionality prior to returning to service.

should be applied at all terminals, even if additions or modifications were executed at only one terminal.

Local testing will verify:

- Relay firmware version is acceptable.
- Phasing between utilities
- Automated or steady state testing and/or relay setting files verification.
- Functional logic testing to confirm the appropriate actions of relay(s). Only the functions utilized by the relay need to be confirmed.
- Communication channel functionality.

Prior to end to end testing all of the above tests, in addition to any local tests should be executed and documented in accordance with the member company's specific work practices, administrative policies and procedures.

End to End Testing

Companies performing end to end testing of line protection schemes shall adhere to the following testing protocol. It is expected that if a company initiates a request for end to end testing that arrangements will be made to satisfy their request. An effort should be made to satisfy both companies' requirements.

For the purpose of testing a line protection scheme, a representative from the initiating company of any new, modified or questionable system shall be responsible to contact an appropriate party at all of the affected interconnected companies. Once this contact is established, a Responsible Designee (RD) from each affected company shall be identified. These parties shall then jointly determine schedules, testing procedures and coordination of the affected operating departments. The equipment outage(s) will be requested and scheduled with PJM by the initiating company.

The initiating company shall provide to each affected utility the detailed test plan required to conduct the testing unless otherwise agreed upon by the affected utilities. The work plan and schedule shall contain the following key information:

- Names and telephone numbers of key personnel
- Substation telephone numbers

- Work scope, expected interface and support
- Start date, time and duration
- Line / Equipment in-service date and time
- End to end test plans
- Test set and software used including any relevant firmware or software version numbers.

The RD of the initiating company is to be considered the lead individual among all participating companies for the requested end to end testing.

It is the responsibility of each company's RD to inform all affected departments within that company of the impending testing. This includes the department responsible for protection review and analysis.

All participating companies shall coordinate with each other and allow each other ample time and opportunity to address any issues or conditions identified through the testing process. At times, this may require patience among the various participating groups.

All affected operations and testing groups must be notified that tests are complete and that the protection system is released for service. In the event that the tests were unacceptable, notification must also be made indicating any appropriate contingency plans to be followed. If either company requests the remote end results it is expected they will be shared in some form.

Appendix A

Line 101: Station A – Station B (100 mi) [Station A SEL-421-5, Station B SEL-421-5] DCB

<u>Test</u>	<u>Type of Fault</u>	<u>Test Duration (Cycles)</u>	<u>Fault Location % of Line from A</u>	<u>Fault Location</u>	<u>Carrier Switch</u>	<u>Expected Result At A</u>	<u>Expected Result At B</u>
1	3PH	5		In A Zone 3, Out of B Zone 2	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TARGETS, NO EVENT RECORD
2	BC	5		In A Zone 3, Out of B Zone 2	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TARGETS, NO EVENT RECORD
3	AG	5		In A Zone 3, Out of B Zone 2	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TRIP, 67G2 A GND
4	BC	100		A 500 Bus	Off	NO TARGETS, NO EVENT RECORD	Z2PT TRIP, PHASE BC
5	AG	100		A 500 Bus	Off	NO TARGETS, NO EVENT RECORD	51S1 TRIP, 67G2 A GND
6	3PH	5		A 500 Bus	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TRIP, Z2P ABC
7	BC	5		A 500 Bus	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TRIP, Z2P BC
8	AG	5		A 500 Bus	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	NO TRIP, Z2G/67G2 A GND
9	3PH	5	5%	A - B	On	Z1P TRIP, PHASE ABC	Z2P PILOT TRIP, PHASE ABC
10	BC	5	5%	A - B	On	Z1P TRIP, PHASE BC	Z2P PILOT TRIP, PHASE BC
11	AG	5	5%	A - B	On	Z1G/67G2 PILOT TRIP, A GND	Z2G/67G2 PILOT TRIP, A GND
12	3PH	5	50%	A - B	On	Z1P TRIP, PHASE ABC	Z1P TRIP, PHASE ABC
13	BC	5	50%	A - B	On	Z1P TRIP, PHASE BC	Z1P TRIP, PHASE BC
14	AG	5	50%	A - B	On	Z1G/67G2 PILOT TRIP, A GND	Z1G/67G2 PILOT TRIP, A GND
15	3PH	5	95%	A - B	On	Z2P PILOT TRIP, PHASE ABC	Z1P TRIP, PHASE ABC
16	BC	5	95%	A - B	On	Z2P PILOT TRIP, PHASE BC	Z1P TRIP, PHASE BC
17	AG	5	95%	A - B	On	Z2G/67G2 PILOT TRIP, A GND	Z1G/67G2 PILOT TRIP, A GND
18	3PH	5		B 500 Bus	On	NO TRIP, Z2P ABC	CARRIER SEND, NO TARGETS, NO EVENT RECORD
19	BC	5		B 500 Bus	On	NO TRIP, Z2P BC	CARRIER SEND, NO TARGETS, NO EVENT RECORD
20	AG	5		B 500 Bus	On	NO TRIP, Z2G/67G2 A GND	CARRIER SEND, NO TARGETS, NO EVENT RECORD
21	BC	100		B 500 Bus	Off	Z2PT TRIP, PHASE BC	NO TARGETS, NO EVENT RECORD
22	AG	100		B 500 Bus	Off	51S1 TRIP, A GND	NO TARGETS, NO EVENT RECORD
23	3PH	5		In B Zone 3, Out of A Zone 2	On	NO TARGETS, NO EVENT RECORD	CARRIER SEND, NO TARGETS, NO EVENT RECORD
24	BC	5		In B Zone 3, Out of A Zone 2	On	NO TARGETS, NO EVENT RECORD	CARRIER SEND, NO TARGETS, NO EVENT RECORD
25	AG	5		In B Zone 3, Out of A Zone 2	On	NO TRIP, 67G2 A GND	CARRIER SEND, NO TARGETS, NO EVENT RECORD
26	3PH	100		In B Zone 3, In A Zone 4	On	Z4PT TRIP, PHASE ABC	CARRIER SEND, NO TARGETS, NO EVENT RECORD
27	BC	100		In B Zone 3, In A Zone 4	On	Z4PT TRIP, PHASE BC	CARRIER SEND, NO TARGETS, NO EVENT RECORD
28	AG	100		In B Zone 3, In A Zone 4	On	Z4GT TRIP, 51S1 TRIP, A GND	CARRIER SEND, NO TARGETS, NO EVENT RECORD
29	3PH	100		In A Zone 3, In B Zone 4	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	Z4PT TRIP, PHASE ABC
30	BC	100		In A Zone 3, In B Zone 4	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	Z4PT TRIP, PHASE BC
31	AG	100		In A Zone 3, In B Zone 4	On	CARRIER SEND, NO TARGETS, NO EVENT RECORD	Z4GT TRIP, 51S1 TRIP, A GND

Line 101: Station A – Station B (100 mi) [Station A SEL-421-5, Station B SEL-421-5] POTT

<u>Test</u>	<u>Type of Fault</u>	<u>Test Duration (Cycles)</u>	<u>Fault Location % of Line from A</u>	<u>Fault Location</u>	<u>Expected Result At A</u>	<u>Expected Result At B</u>
1	3PH	5		In A Zone 3, Out of B Zone 2	NO PERMISSIVE SIGNAL SENT	NO TARGETS, NO EVENT RECORD
2	BC	5		In A Zone 3, Out of B Zone 2	NO PERMISSIVE SIGNAL SENT	NO TARGETS, NO EVENT RECORD
3	AG	5		In A Zone 3, Out of B Zone 2	NO PERMISSIVE SIGNAL SENT	NO TRIP, 67G2 A GND
4	BC	100		A 500 Bus	NO PERMISSIVE SIGNAL SENT	Z2PT TRIP, PHASE BC
5	AG	100		A 500 Bus	NO PERMISSIVE SIGNAL SENT	51S1 TRIP, 67G2 A GND
6	3PH	5		A 500 Bus	NO PERMISSIVE SIGNAL SENT	NO TRIP, Z2P ABC
7	BC	5		A 500 Bus	NO PERMISSIVE SIGNAL SENT	NO TRIP, Z2P BC
8	AG	5		A 500 Bus	NO PERMISSIVE SIGNAL SENT	NO TRIP, Z2G/67G2 A GND
9	3PH	5	5%	A - B	Z1P TRIP, PHASE ABC	Z2P PILOT TRIP, PHASE ABC
10	BC	5	5%	A - B	Z1P TRIP, PHASE BC	Z2P PILOT TRIP, PHASE BC
11	AG	5	5%	A - B	Z1G/67G2 PILOT TRIP, A GND	Z2G/67G2 PILOT TRIP, A GND
12	3PH	5	50%	A - B	Z1P TRIP, PHASE ABC	Z1P TRIP, PHASE ABC
13	BC	5	50%	A - B	Z1P TRIP, PHASE BC	Z1P TRIP, PHASE BC
14	AG	5	50%	A - B	Z1G/67G2 PILOT TRIP, A GND	Z1G/67G2 PILOT TRIP, A GND
15	3PH	5	95%	A - B	Z2P PILOT TRIP, PHASE ABC	Z1P TRIP, PHASE ABC
16	BC	5	95%	A - B	Z2P PILOT TRIP, PHASE BC	Z1P TRIP, PHASE BC
17	AG	5	95%	A - B	Z2G/67G2 PILOT TRIP, A GND	Z1G/67G2 PILOT TRIP, A GND
18	3PH	5		B 500 Bus	NO TRIP, Z2P ABC	NO PERMISSIVE SIGNAL SENT
19	BC	5		B 500 Bus	NO TRIP, Z2P BC	NO PERMISSIVE SIGNAL SENT
20	AG	5		B 500 Bus	NO TRIP, Z2G/67G2 A GND	NO PERMISSIVE SIGNAL SENT
21	BC	100		B 500 Bus	Z2PT TRIP, PHASE BC	NO PERMISSIVE SIGNAL SENT
22	AG	100		B 500 Bus	51S1 TRIP, A GND	NO PERMISSIVE SIGNAL SENT
23	3PH	5		In B Zone 3, Out of A Zone 2	NO TARGETS, NO EVENT RECORD	NO PERMISSIVE SIGNAL SENT
24	BC	5		In B Zone 3, Out of A Zone 2	NO TARGETS, NO EVENT RECORD	NO PERMISSIVE SIGNAL SENT
25	AG	5		In B Zone 3, Out of A Zone 2	NO TRIP, 67G2 A GND	NO PERMISSIVE SIGNAL SENT
26	3PH	100		In B Zone 3, In A Zone 4	Z4PT TRIP, PHASE ABC	NO PERMISSIVE SIGNAL SENT
27	BC	100		In B Zone 3, In A Zone 4	Z4PT TRIP, PHASE BC	NO PERMISSIVE SIGNAL SENT
28	AG	100		In B Zone 3, In A Zone 4	Z4GT TRIP, 51S1 TRIP, A GND	NO PERMISSIVE SIGNAL SENT
29	3PH	100		In A Zone 3, In B Zone 4	NO PERMISSIVE SIGNAL SENT	Z4PT TRIP, PHASE ABC
30	BC	100		In A Zone 3, In B Zone 4	NO PERMISSIVE SIGNAL SENT	Z4PT TRIP, PHASE BC
31	AG	100		In A Zone 3, In B Zone 4	NO PERMISSIVE SIGNAL SENT	Z4GT TRIP, 51S1 TRIP, A GND

