AEP Ohio Technical Requirements for Interconnection Service

All Distributed Resources requirements are subject to Company's Minimum Requirements for Interconnection Service and Ohio Administrative Code 4901:1-22 (OAC). These Technical Requirements by the Company shall not be in conflict with any requirements in the OAC. It is acknowledged that IEEE Standard 1547 "Standard for Interconnecting Distributed Resources with Electric Power Systems" (IEEE 1547)[1] is the basis for interconnection Technical Requirements for most jurisdictions. The intent is to utilize IEEE 1547 requirements and to supplement those with a minimal number of additional requirements where appropriate. The purpose of a minimal number of Company requirements not included in IEEE 1547 is to add clarity to some IEEE 1547 sections and to specify requirements for issues not addressed in IEEE 1547. These Technical Requirements apply to all Distributed Resource technologies including synchronous machines, induction machines, or static power inverters/converters.

The interconnection system hardware and software used by a Distributed Resource to meet these Technical Requirements do not have to be located at the Point of Common Coupling. However, the Technical Requirements shall be met at the Point of Common Coupling.

A table summarizing the Distributed Resource Technical Requirements is attached as Appendix 1. The pertinent IEEE 1547 clause number(s) are shown in this table.

Basic Technical Requirements:

The Technical Requirements in IEEE 1547 cover the following areas, Voltage Regulation, Voltage Disturbances, Harmonic Current Injection, Direct Current Injection, Grounding Scheme Compatibility, Inadvertent Energizing, Monitoring Operation, Isolation Device, Withstand Performance, Paralleling Device, Response to Area EPS Faults, Reclosing Coordination, Unintentional Islanding, Voltage and Frequency Detection, Abnormal Voltage or Frequency, Reconnection Following a Disturbance, Secondary Grid and Spot Network Systems, and Testing and Maintenance.

Testing:

A Distributed Resource proposing to interconnect with the Company's transmission and distribution systems (AEP Ohio System) must be tested as per IEEE 1547 Clause 5 to demonstrate that the interconnection system meets the requirements of IEEE 1547 Clause 4. Documentation of the results of the Design Test and Production Tests shall be provided to AEP Ohio at the time of application unless such tests are to be conducted as part of the Commissioning Tests.

When the interconnection system of the Distributed Resource uses an assembly of discrete components, documentation of testing must be provided to AEP Ohio at the time of application to confirm the compatibility of the discrete components to properly function together. Otherwise AEP Ohio may require the Design Test to be conducted as part of the Commissioning Tests.

Written test procedures shall be approved by AEP Ohio for all tests to be performed as Commissioning Tests. To avoid delay, these test procedures should be submitted to AEP Ohio well in advance of the scheduled date of the Commissioning Tests.

A suggested format for test proposal submission and test result reporting can be found in Appendix 3 – AEP Guide for Testing and Reporting per IEEE 1547.1.

Additional Technical Requirements:

Circuit Breaker - If a main circuit breaker (or circuit switcher) between the interconnection transformer and the AEP Ohio System is required, the device must comply with the applicable

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[1] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 443 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 (http://standards.ieee.org/).

current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.

Main Disconnect Switch (Voltages exceeding 480 volts) – A gang operated disconnecting device must be located at the Point of Common Coupling for all three phase interconnections. In all cases the disconnecting device must be clearly labeled, readily accessible to AEP Ohio personnel for use at all times and suitable for use by AEP Ohio as a protective tagging location. The disconnecting device shall have a visible open gap when in the open position and be capable of being locked in the open position.

The disconnecting device must have a ground grid designed in accordance with specifications to be provided by AEP Ohio. Operation of the device must be restricted to AEP Ohio personnel and properly trained operators designated by the interconnection customer. The disconnecting device must comply with the applicable current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.

Terminating Structure – When a new interconnection line is required, the interconnection customer shall provide a suitable structure to terminate the interconnection line. The customer is responsible for ensuring that terminating structure or substation structural material strengths are adequate for all requirements, incorporating appropriate safety factors. AEP Ohio will provide line tension information for maximum dead-end. The structure must be designed for the maximum line tension along with an adequate margin of safety.

Substation electrical clearances shall meet or exceed the requirements of the National Electrical Safety Code. Installation of disconnect switches, bus support insulators and other equipment shall comply with accepted industry practices.

Surge arresters shall be selected to coordinate with the BIL rating of major equipment components and shall comply with recommendations set forth in the applicable current ANSI Standard C62.2 that specifies the requirements for surge arresters and other surge protection devices.

Momentary Paralleling – For situations where the proposed Distributed Resource will only be operated in parallel with the AEP Ohio System for a short duration (less than 100 milliseconds), as in a make-before-break automatic transfer scheme, the requirements of IEEE 1547 do not apply except as noted in Clause 4.1.4. All make-before-break automatic transfer switch systems proposed by the interconnection customer must comply with UL 1008 and be listed by a nationally recognized testing laboratory.

Voltage Unbalance – The interconnection customer is responsible for operating the proposed Distributed Resource such that the voltage unbalance attributable to the Distributed Resource does not exceed 2.5% at the Point of Common Coupling.

Power Factor - Each Distributed Resource shall be capable of operating at some point within a power factor range from 0.9 leading to 0.9 lagging. Operation outside this range is acceptable provided the reactive power of the Distributed Resource is used to meet the reactive power needs of the electrical loads within the interconnection customer’s facility or that reactive power is otherwise provided under tariff by AEP Ohio. The interconnection customer shall notify AEP Ohio if it is using the Distributed Resource for power factor correction.

System Stability – AEP Ohio may require a stability study for Distributed Resources if the aggregate generation is greater than 10 MW and in an area where there are known or posted stability limitations to generation located in the general electrical vicinity (e.g., three or four transmission voltage level busses from the transmission voltage bus serving the distribution circuit where the Distributed Resource proposes to interconnect.

Maintenance and Testing – The interconnection customer is responsible for the periodic scheduled maintenance on the interconnection system of the Distributed Resource (relays, interrupting devices, control schemes, and batteries that involve the protection of the AEP Ohio

System). Unless the equipment manufacturer provides study results that demonstrate the need for less frequency, interconnection systems that depend upon a battery for proper function shall be checked and logged once per month for proper voltage. At least once every four years, the battery must be either replaced or a discharge test performed.

A periodic maintenance program is to be established in accordance with the requirements of IEEE 1547. AEP Ohio may examine copies of the periodic test reports or inspection logs associated with the periodic maintenance program. Upon request, AEP Ohio shall be informed of the next scheduled maintenance and be able to witness the maintenance performed and any associated testing.

Monitoring – AEP Ohio reserves the right, at AEP Ohio's initial expense, to install special test equipment as may be required to perform a disturbance analysis and monitor the operation and control of the Distributed Resource to evaluate the quality of power produced by the Distributed Resource.

Evaluation of System Impact:

A Distributed Resource proposing to interconnect to the AEP Ohio System may have significant impact on the safety and reliability of one or more of the following portions of the electrical power system; the AEP Ohio Distribution System, the AEP Ohio Transmission System, the Distribution or Transmission System of a third party (called an Affected System) and the electrical system where the Distributed Resource is to be connected. AEP Ohio shall not be responsible for the evaluation of the safety and reliability impacts on the electrical system where the Distributed Resource is to be connected. AEP Ohio approval of a Distributed Resource interconnection should not be construed as an endorsement, confirmation, warranty, guarantee, or representation concerning the safety, operating characteristics, durability, or reliability of the Distributed Resource facility and the electrical system where it is connected.

AEP Ohio Distribution System Impact –

AEP Ohio is responsible for evaluating the system impact of a proposed Distributed Resource interconnection based upon the information provided in the interconnection application once the application is considered complete.

A study to determine system impact will be performed based upon the interconnection request's position in the Queue and the applicable time limits established by the regulatory authority having jurisdiction. The study time limits and study scope vary depending upon the regulatory authority and the type, size and proposed use of the Distributed Resource.

AEP Ohio supports limited study and the use of a screening process to expeditiously identify and approve Distributed Resources that can be interconnected without significant system impact. AEP Ohio screening criteria is based on the OAC.

Additional study time is generally required to evaluate Distributed Resources that are not pre-certified. The exception may be for Distributed Resources that have been evaluated previously by AEP Ohio and were found to meet the Technical Requirements including the necessary testing.

The possible outcomes of the system impact study could include the following:

1) The proposed Distributed Resource interconnection meets the Technical Requirements and there are no system impacts that would require modification or upgrade to either AEP Ohio facilities or the Distributed Resource installation;

2) The proposed Distributed Resource interconnection does not meet the Technical Requirements and modifications or changes are required to either AEP Ohio facilities or the Distributed Resource installation;

3) The proposed Distributed Resource interconnection would result in negative system impact and modifications or changes are required to either AEP Ohio facilities or the Distributed Resource installation;

4) The proposed Distributed Resource interconnection requires new AEP Ohio facilities.

The potential distribution system impacts listed in Appendix 2 may need to be examined as part of the system impact study.

AEP Ohio Transmission System Impact –

AEP Ohio will determine if there may be an impact to the AEP Ohio transmission system (including any transmission system stability impact) or an impact to a third party's system when the interconnection occurs on the AEP Ohio distribution system.

AEP Ohio will coordinate processing the interconnection request to assure the proper process is followed and all required milestones are met.

Affected System Impact –

AEP Ohio will review each request for interconnection to the AEP Ohio distribution system to determine if the potential exists for impact to a third party's system. For example, the distribution systems of several Rural Electric Cooperatives are interconnected to AEP Ohio distribution feeders.

If the potential exists for an impact to their system, AEP Ohio will notify the third party of the proposed interconnection request and coordinate processing the interconnection request to assure that the proper process is followed and all required milestones are met.

Appendix 1

Distributed Resource Technical Requirements

Attribute	Requirement
Voltage Regulation	IEEE 1547 - Clause 4.1.1
Voltage Disturbances	IEEE 1547 - Clause 4.3.2
Harmonic Current Injection	IEEE 1547 - Clause 4.3.3
Direct Current Injection	IEEE 1547 - Clause 4.3.1
Grounding Scheme Compatibility	IEEE 1547 - Clause 4.1.2
Inadvertent Energization	IEEE 1547 - Clause 4.1.5
Monitoring Provisions	IEEE 1547 - Clause 4.1.6
Isolation Device	IEEE 1547 - Clause 4.1.7
Withstand Performance	IEEE 1547 - Clause 4.1.8.1 and Clause 4.1.8.2
Paralleling Device	IEEE 1547 - Clause 4.1.8.3
Response to Area EPS Faults	IEEE 1547 - Clause 4.2.1
Reclosing Coordination	IEEE 1547 - Clause 4.2.2
Unintentional Islanding	IEEE 1547 - Clause 4.4.1
Abnormal Voltage	IEEE 1547 - Clause 4.2.3
Abnormal Frequency	IEEE 1547 - Clause 4.2.4
Reconnection Following a Disturbance	IEEE 1547 - Clause 4.2.6
Secondary Grid and Spot Network Systems	IEEE 1547 - Clause 4.1.4
Testing	IEEE 1547 - Clause 5
Periodic Interconnection Tests	IEEE 1547 - Clause 5.5
Circuit Breaker	Meet appropriate ANSI C37 standard
Disconnect Switch	Three phase unit gang operated at Point of Common Coupling
Terminating Structure	Adequate structural material strength suitable to terminate line
Surge Arresters	Meet applicable ANSI C62.2 standard
Momentary Paralleling	Comply with Underwriter's Laboratories Standard 1008 and IEEE 1547 – Clause 1.3
Voltage Unbalance	Unbalance attributable to Distributed Resource 2.5% or less
System Stability	Study required for units greater than 10 MW when limitations exist

Appendix 2

Potential Distribution System Impacts

Voltage Regulation - With the addition of the Distributed Resource, the voltage level on both the primary and secondary must be maintained within acceptable limits for both on peak and off peak conditions.

1) Reverse power flow through voltage regulators or load tap changers may cause the regulator or load tap changer to regulate the voltage incorrectly.

2) Improper settings of the Distributed Resource controls may result in the steady state voltage straying outside the + or - 5% limits at the point of common coupling on a 120 volt basis.

3) Low voltage may be experienced after a temporary fault or when restoring service after a permanent fault if the presence of the Distributed Resource is essential to the maintenance of adequate voltage.

4) The loss of Distributed Resource synchronous machine exciters may cause excessive reactive power losses and low voltages on a circuit.

5) The presence of Distributed Resources with varying output (e.g. wind turbines, photovoltaic cells, etc.) may cause excessive switching of capacitor banks and/or an excessive number of regulator or load tap changer operations.

6) When line drop compensators are used on a circuit, the presence of Distributed Resources may significantly alter the intended regulation scheme.

7) The presence of Distributed Resources on a secondary system may cause the off peak voltage level to exceed its upper limit.

8) The Distributed Resource owner could experience periods when his unit(s) trips off line from overvoltage due to system voltage excursions.

Voltage Flicker - Several Distributed Resource technologies have the potential for creating objectionable voltage flicker. In extreme cases the size of the Distributed Resource may need to be limited to prevent objectionable flicker or system improvements may be necessary to limit the voltage flicker. Possible flicker sources include:

1) Wind turbines may produce rapidly varying output due to changes in wind speed, wind turbulence, intensity, tower shadowing effects and blade pitching.

2) Photovoltaic (PV) installations may produce rapidly varying output due to intermittent cloud cover over the cells.

3) Reciprocating engine Distributed Resources may be produce rapid output fluctuations caused by engine misfiring due to low quality fuel.

4) Induction machine Distributed Resources may produce voltage flicker due to current inrush when they are connected.

5) Synchronous machine Distributed Resources may produce voltage flicker due to poor voltage matching and phase angle synchronization at contact closure.

6) Power inverter based Distributed Resources may not have soft start technology to limit the rate of change of power output at starting.

7) Interaction of Distributed Resources with other devices such as voltage regulators, load tap changers and switched capacitor banks may produce objectionable voltage flicker.

Overcurrent Protection and Protective Device Coordination - With the addition of a Distributed Resource on a circuit, another source of fault current is introduced. The available fault current at any location on the feeder will depend upon the type of fault (e.g. line-to-ground, three phase, double-line-to-ground, etc.), the fault impedance, and the status of the Distributed Resource on the feeder (i.e. on or off line). Each Distributed Resource technology has its own unique fault current characteristics.

The presence of Distributed Resources may create several problems with overcurrent protection and the coordination of protective devices. Some of the problems include:

1) The “reach” of overcurrent protective devices may be reduced due to a reduction in the fault current contribution from the station source with Distributed Resources on a feeder. For faults located downstream from a Distributed Resource, the fault current contribution from the station source will be reduced when the Distributed Resource unit is on line.

2) Recloser to fuse coordination may no longer exist with the introduction of a Distributed Resource on the feeder so fuses may blow for temporary faults.

3) Sectionalizers may misoperate if the Distributed Resource maintains voltage when the sectionalizer should be "counting" an operation.

4) Nuisance tripping of a circuit recloser or station breaker may occur from a fault located on an adjacent feeder due to the fault current contribution from the Distributed Resource.

5) The presence of an interconnection transformer with a primary voltage wye grounded winding connection and a secondary voltage delta connection at the Distributed Resource can desensitize ground fault relays and the ground fault settings on recloser controls.

6) The introduction of Distributed Resource to a secondary spot or grid network system can cause nuisance trips of protectors and protector cycling and may lead to out of phase protector closing resulting in equipment damage.

7) The presence of a Distributed Resource may exacerbate cold load pickup problems following a feeder outage.

8) The addition of a Distributed Resource may increase the available fault current to the point where utility system or customer owned protective device fault interrupting ratings are exceeded.

9) If the Distributed Resource remains on the feeder after a protective device opens for any reason, then the protective device may reclose with the system voltage and the Distributed Resource voltage out of synchronism.

10) Distribution automation schemes may be adversely affected by the introduction of Distributed Resources.

11) System under frequency conditions may result in feeder or transformer overload conditions.

Harmonic Current Injection - Several Distributed Resource technologies have the potential for introducing harmonic distortion. Possible harmonic issues include:

Appendix 2

1) Rotating machines produce 3rd harmonic distortion. Machines having a pitch of either 5/6 and 11/16 introduce the most distortion with 2/3 pitch being the preferred pitch to minimize distortion.

2) Inverter based Distributed Resources may inject harmonic voltages and currents into the utility grid or may serve as a system sink for harmonics.

3) Wye-wye transformer connected Distributed Resources and single phase Distributed Resources have the potential for being the worst harmonic sources.

Other Issues - Several other issues relating to the interconnection of Distributed Resources need to be considered. Potential problems to look for include:

1) Voltage on unfaulted phases may approach 1.73 times nominal during single line to ground faults when delta-wye or delta-delta connected transformer banks are used for the Distributed Resource transformation.

2) Resonant overvoltages can occur if a synchronous or induction generator Distributed Resource is isolated with capacitors during line to ground faults.

3) Single phase switching of a delta connected Distributed Resource transformer bank may create ferroresonant overvoltage conditions.

4) Distributed Resources may present utility worker and public safety concerns by inadvertently re-energizing the electric power system during abnormal system conditions.

5) The addition of Distributed Resource may overload conductors or equipment.

6) The presence of a Distributed Resource may defeat attempts to clear fault conditions by continuing to energize the feeder during fault events.

7) Induction and synchronous machine Distributed Resources may be over excited by the presence of a capacitor bank in an unintentional islanding situation and produce high voltages in the island.

8) Inverter based Distributed Resources may inject direct current onto the feeder causing transformer saturation.

9) When a grounded-wye high-side/delta low-side connected transformer bank is used to connect a Distributed Resource, circulating current in the delta winding may result in transformer overloading. This transformer connection allows zero sequence current to circulate in the delta winding.

10) When feeders are switched from their normal configuration to affect load transfers or to restore power to customers during outage situations, the presence of a Distributed Resource may create voltage regulation problems, objectionable voltage flicker, improper protective device operation and coordination or other problems.

Appendix 3

AEP Guide for Testing and Reporting per IEEE 1547.1

The purpose of this guide is to provide a suggested simplified format for test proposal submission and test result reporting. It will provide direction for and set AEP expectations of the customer-generator for the testing and reporting per IEEE 1547.1. IEEE 1547.1 specifies the type, production, and commissioning tests that shall be performed to demonstrate that the interconnection functions and equipment of the distributed resources conform to IEEE standard 1547. AEP recognizes the detail of IEEE 1547.1 can be intimidating at first glance. Once the document structure is understood, the customer-generator task becomes nothing more than a series of items for which to test and report results or report manufacturer test results. This guide does not remove the customer-generator's responsibility for reading, understanding, and complying with all of the IEEE 1547.1 contents, as well as any applicable local codes, standards, legislation, or commission order.

When AEP performs a system impact study in response to an application for interconnection of generation equipment 20 megawatts or less the customer-generator may need to test the interconnection system (ICS) to assure IEEE 1547 compliance. It is the customer-generator's responsibility to clearly communicate its testing proposal and test results report to AEP. The contents of this guide will help the customer-generator navigate IEEE 1547.1 when ICS testing is necessary.

IEEE 1547.1 is organized into 8 distinct articles. While the entire document is important, there are specific articles and sub-articles that warrant highlighting. They are:

1. Sub-article 4.3, Measurement accuracy and calibration of the testing equipment
    a. When the customer-generator provides measurement equipment calibration traceability, place this documentation at the front of the test report.
2. Sub-article 4.4, Product information
    a. This sub-article describes when special testing parameters or criteria are to be noted in the test report.
3. Sub-article 4.5, Test reports
    a. In the test reports AEP expects to see a given section containing test results titled with the IEEE 1547.1 sub-article number of the test. This practice will keep the test reports clear and unambiguous. For example:
        i. An ***Over-voltage Magnitude*** Type test result would be titled with **5.2.1.2 Over-voltage Magnitude test results**. (See Example A)
        ii. An ***Over-voltage Timing*** Type test would be titled with **5.2.1.3 Overvoltage Timing test results**. (See Example A)
        iii. A ***Synchronization*** Production test result would be titled with **6.3 Synchronization test results**. (follow same format as Example A)
        iv. A ***Revised settings*** Commissioning test result would be titled with **7.6 Revised Settings test results**. (follow same format as Example A)
    b. Unless the test purpose or procedure outlined in each sub-article is modified, the test reports need only include test results including unit measured. Test reports containing dimensionless results will be returned as unacceptable. It will be understood that any and all test related purpose, procedure, requirement, and criteria will be contained within the identified IEEE 1547.1 sub-article and does not bear repeating in the customer-generator submitted test reports.

c. Example B (Distributed Generation IEEE 1547.1 Testing Matrix) is a template spreadsheet that allows the customer to indicate how they plan to comply with a particular IEEE 1547.1 test and indicate devices, documents, and notes that relate to a given test.

4. Article 5, Type tests

   a. It is the responsibility of the customer-generator to determine if any of the Type tests have been addressed by the manufacturer.
   b. Type tests performed by the manufacturer shall be clearly identified by indicating on the manufacturer literature which Type test is addressed using the Type test number as described above. (See Example C)

5. Article 6, Production tests

   a. It is the responsibility of the customer-generator to determine if any of the Production tests have been addressed by the manufacturer.

   b. Production tests performed by the manufacturer shall be clearly identified by indicating on the manufacturer literature which Production test is addressed using the Production test number as described above. (See Example C)

6. Article 7, Commissioning tests

   a. Sub-article 7.1.2 indicates what test procedures must be submitted to AEP for approval prior to testing.

      i. The submitted customer-generator test procedures can simply be a list of the sub-article numbers of the Type, Production, and Commissioning tests that will be conducted by the customer-generator. It will be understood that any and all test related purpose, procedure, requirement, and criteria will be contained within the identified IEEE 1547.1 sub-article and does not bear repeating in the customer-generator submitted test procedures. (See Example B)

   b. Any Type or Production sub-article number test not appearing in the list from item 7.a.i of this document must appear as satisfied per item 5.b or 6.b. (See Example C)

7. Article 8, Periodic interconnection tests

   a. The periodic test schedule shall be included in the test results report.

The following Examples on pages 11 – 20 are representative of acceptable IEEE 1547.1 documentation.

Example D is a suggested cover sheet format for the customer’s IEEE 1547.1 test results report package, which lists all of the support documents they plan to supply to support their claim of IEEE 1547 compliance.

Appendix 3

Example A

DISTRBUTED GENERATION IEEE 1547.1 TESTING RESULTS SUMMARY

The tables below summarize the results obtained from testing. Nominal/Actual may be rounded. Deviation is absolute.

5.2.1.2 Over-voltage Magnitude

A-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121.1	50
2	121	121	25
3	121	121.2	150
4	121	121	40
5	121	121	35

B-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121.1	50
2	121	121.1	50
3	121	121	25
4	121	121	-45
5	121	121	30

C-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121	5
2	121	121	15
3	121	121	-5
4	121	121	20
5	121	121	15

3-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121.1	70
2	121	121	25
3	121	121.1	90
4	121	121	40
5	121	121	35

5.2.1.2 Over-voltage Magnitude

A-Phase Over-Voltage Mid Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	138.5	138.6	55
2	138.5	138.5	15
3	138.5	138.5	10
4	138.5	138.5	30
5	138.5	138.5	45

Appendix 3

B-Phase Over-Voltage Mid Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	138.5	138.5	20
2	138.5	138.5	30
3	138.5	138.5	10
4	138.5	138.6	80
5	138.5	138.6	70

C-Phase Over-Voltage Mid Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	138.5	138.5	20
2	138.5	138.6	55
3	138.5	138.5	40
4	138.5	138.5	10
5	138.5	138.6	50

3-Phase Over-Voltage Mid Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	138.5	138.6	70
2	138.5	138.5	25
3	138.5	138.6	90
4	138.5	138.5	40
5	138.5	138.5	35

5.2.1.2 Over-voltage Magnitude

A-Phase Over-Voltage High Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156	15
2	156	156.1	55
3	156	156.1	60
4	156	156.1	50
5	156	156.1	75

B-Phase Over-Voltage High Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156	20
2	156	156	30
3	156	156	10
4	156	156	40
5	156	156	45

C-Phase Over-Voltage High Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156.1	65
2	156	156	20
3	156	156	40
4	156	156	10
5	156	156	30

Appendix 3

3-Phase Over-Voltage High Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156.1	80
2	156	156.1	75
3	156	156.1	60
4	156	156.1	90
5	156	156.1	55

5.2.1.3 Over-voltage Timing

Low Time Delay

Trial	Nominal (ms)	Actual (ms)	Deviation (ms)
1	20	16.7	-3.3
2	20	18	-2
3	20	17	-3
4	20	16.8	-3.2
5	20	17.2	-2.8

Mid Time Delay

Trial	Nominal (s)	Actual (s)	Deviation (ms)
1	1.52	1.525	4.8
2	1.52	1.525	4.6
3	1.52	1.525	5.1
4	1.52	1.525	5.3
5	1.52	1.525	4.9

High Time Delay

Trial	Nominal (s)	Actual (s)	Deviation (ms)
1	3.02	3.025	4.6
2	3.02	3.025	5.2
3	3.02	3.025	4.7
4	3.02	3.025	4.6
5	3.02	3.025	5.4

Appendix 3

Example B

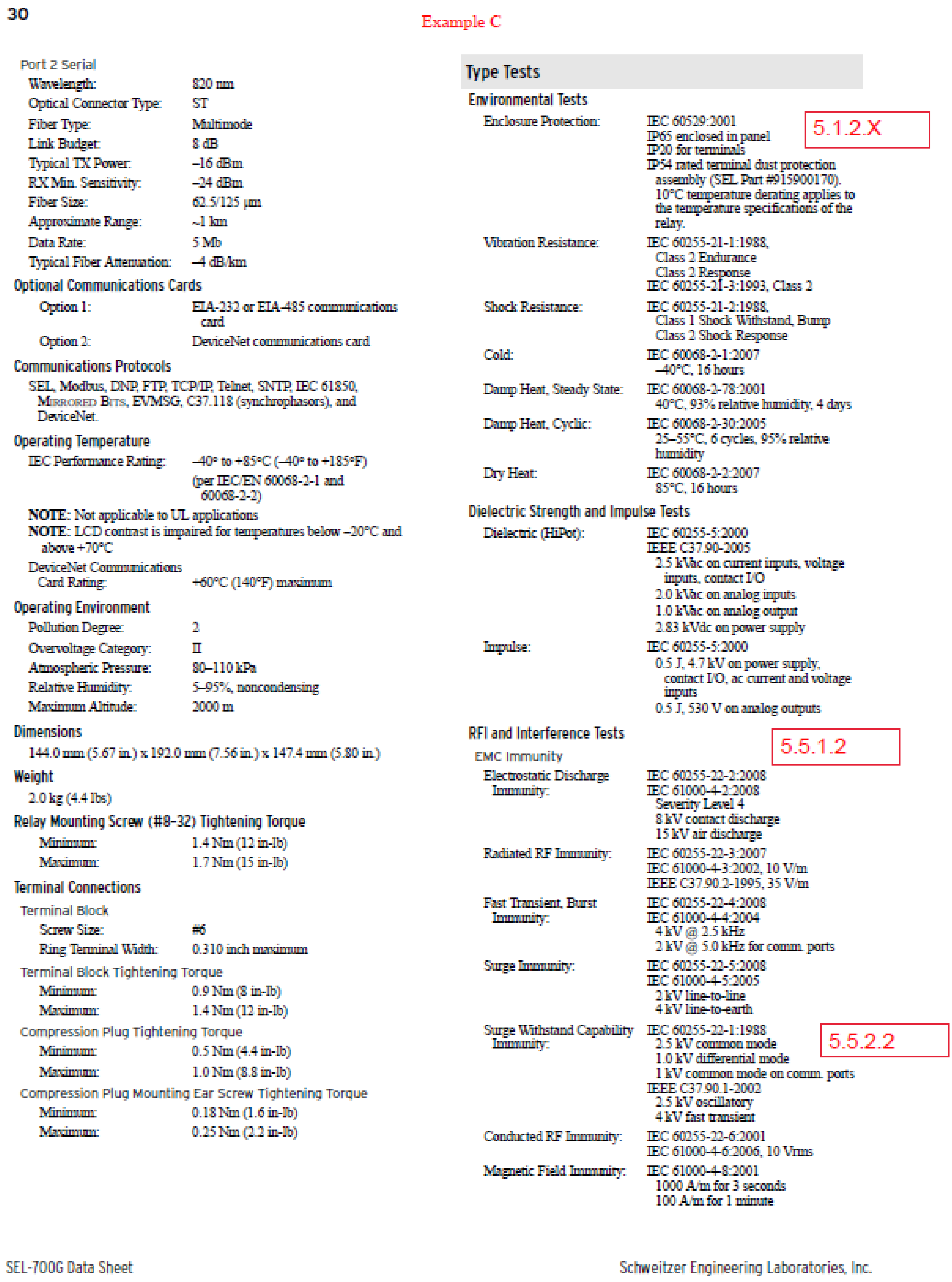
DISTRIBUTED GENERATION IEEE 1547.1 TESTING MATRIX

Facility Name	ABC Company	DG Type	Turbine
Facility Location	Anytown, OH	Date	10/11/2016
Total Generation	3500 KW		

Line	IEEE 1547.1 ID	IEEE 1547.1 Test	Type / Production Test	Field Test per 1547.1	Not Applicable	Compliance Device (Equipment under Test, EUT)	Referenced Document(s)	Notes
1	5.1.2.1	Operational Temperature	X			SEL700G+ Relay	700G_DS_20160334	Page 30
2	5.1.2.2	Storage Temperature	X			SEL700G+ Relay	700G_DS_20160334	Page 30
3	5.2.1.2	Overvoltage - Magnitude	X	X		SEL700G+ Relay	Addendum test procedure	Page 31
4	5.2.1.3	Overvoltage - Trip Time	X	X		SEL700G+ Relay	Addendum test procedure	Page 31
5	5.2.2.2	Undervoltage - Magnitude	X	X		SEL700G+ Relay	Addendum test procedure	Page 31
6	5.2.2.3	Undervoltage - Trip Time	X	X		SEL700G+ Relay	Addendum test procedure	Page 31
7	5.3.1.2	Overfrequency - Magnitude	X			SEL700G+ Relay	700G_DS_20160334	Page 32
8	5.3.1.3	Overfrequency - Trip Time	X			SEL700G+ Relay	700G_DS_20160334	Page 32
9	5.3.2.2	Underfrequency - Magnitude	X			SEL700G+ Relay	700G_DS_20160334	Page 32
10	5.3.2.3	Underfrequency - Trip Time	X			SEL700G+ Relay	700G_DS_20160334	Page 32
11	5.4.1.2	Synchronization - Method 1 - Variation 1	X			SEL700G+ Relay	700G_DS_20160334	Page 34
12	5.4.2.2	Synchronization - Method 1 - Variation 2	X			SEL700G+ Relay	700G_DS_20160334	Page 34
13	5.4.3.2	Synchronization - Method 1 - Variation 3	X			SEL700G+ Relay	700G_DS_20160334	Page 34
14	5.4.4.2	Startup Current - Method 2			X			
15	5.5.1.2	Protection from Electromagnetic Interference	X			SEL700G+ Relay	700G_DS_20160334	Page 30
16	5.5.2.2	Surge withstand Performance	X			SEL700G+ Relay	700G_DS_20160334	Page 30
17	5.5.3.2	Dielectric Test of Paralleling Device		X		SEL700G+ Relay	Addendum test procedure	
18	5.6.2	Limitation of DC Injection (Inverters without XFMR)			X			
19	5.7.1.2	Unintentional Islanding Test		X		SEL700G+ Relay	Addendum test procedure	
20	5.7.2.2	Unintentional Islanding Test for Synchronous Generators		X		SEL700G+ Relay	Addendum test procedure	
21	5.8.1.2	Reverse-Power (for unintentional islanding)	X			SEL700G+ Relay	700G_DS_20160334	Page 32
22	5.8.2.2	Reverse-Power Time Test				SEL700G+ Relay	700G_DS_20160334	Page 32
23	5.9.2	Open Phase		X		SEL700G+ Relay	Addendum test procedure	
24	5.10.2	Reconnect Following Abnormal Condition Disconnect		X		SEL700G+ Relay	Addendum test procedure	
25	5.11.1.1	Harmonics		X		SEL700G+ Relay	Addendum test procedure	
26	5.11.2.1	Harmonics for Synchronous Generators		X		SEL700G+ Relay	Addendum test procedure	
27	5.11.3.1	Harmonics for Induction Generators			X			
28	6.1.2	Response to Abnormal Voltage		X		SEL700G+ Relay	Addendum test procedure	
29	6.2.2	Response to Abnormal Frequency		X		SEL700G+ Relay	Addendum test procedure	
30	6.3.1.1	Synchronization Production		X		SEL700G+ Relay	Addendum test procedure	
31	6.3.2.1	Optional Test for Equipment with Synchronizing Disable			X			
32	7.2	Verifications and Inspections			X			
33	7.4.1	Reverse-Power or Minimum Power Test		X		SEL700G+ Relay	Addendum test procedure	
34	7.4.2	Non-Islanding Functionality Test		X		SEL700G+ Relay	Addendum test procedure	
35	7.4.3	Other Unintentional Islanding Test			X			
36	7.5.1	Cease-to-Energize Functionality		X		SEL700G+ Relay	Addendum test procedure	

Appendix 3

Example C



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Port 2 Serial

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm
RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 km
Data Rate:	5 Mb
Typical Fiber Attenuation:	–4 dB/km

Optional Communications Cards

Option 1:	EIA-232 or EIA-485 communications card
Option 2:	DeviceNet communications card

Communications Protocols

SEL, Modbus, DNP, FTP, TCP/IP, Telnet, SNTP, IEC 61850, Mirrored Bits, EVMSG, C37.118 (synchrophasors), and DeviceNet.

Operating Temperature

IEC Performance Rating:	–40° to +85°C (–40° to +185°F) (per IEC/EN 60068-2-1 and 60068-2-2)

NOTE: Not applicable to UL applications

NOTE: LCD contrast is impaired for temperatures below –20°C and above +70°C

DeviceNet Communications Card Rating:	+60°C (140°F) maximum

Operating Environment

Pollution Degree:	2
Overvoltage Category:	II
Atmospheric Pressure:	80–110 kPa
Relative Humidity:	5–95%, noncondensing
Maximum Altitude:	2000 m

Dimensions

144.0 mm (5.67 in.) x 192.0 mm (7.56 in.) x 147.4 mm (5.80 in.)

Weight

2.0 kg (4.4 lbs)

Relay Mounting Screw (#8-32) Tightening Torque

Minimum:	1.4 Nm (12 in-lb)
Maximum:	1.7 Nm (15 in-lb)

Terminal Connections

Terminal Block

Screw Size:	#6
Ring Terminal Width:	0.310 inch maximum

Terminal Block Tightening Torque

Minimum:	0.9 Nm (8 in-lb)
Maximum:	1.4 Nm (12 in-lb)

Compression Plug Tightening Torque

Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum:	0.18 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

Type Tests

Environmental Tests

5.1.2.X

Enclosure Protection:	IEC 60529:2001 IP65 enclosed in panel IP20 for terminals IP54 rated terminal dust protection assembly (SEL Part #915900170). 10°C temperature derating applies to the temperature specifications of the relay.
Vibration Resistance:	IEC 60255-21-1:1988, Class 2 Endurance Class 2 Response IEC 60255-21-3:1993, Class 2
Shock Resistance:	IEC 60255-21-2:1988, Class 1 Shock Withstand, Bump Class 2 Shock Response
Cold:	IEC 60068-2-1:2007 –40°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2001 40°C, 93% relative humidity, 4 days
Damp Heat, Cyclic:	IEC 60068-2-30:2005 25–55°C, 6 cycles, 95% relative humidity
Dry Heat:	IEC 60068-2-2:2007 85°C, 16 hours

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-5:2000 IEEE C37.90-2005 2.5 kVac on current inputs, voltage inputs, contact I/O 2.0 kVac on analog inputs 1.0 kVac on analog output 2.83 kVdc on power supply
Impulse:	IEC 60255-5:2000 0.5 J, 4.7 kV on power supply, contact I/O, ac current and voltage inputs 0.5 J, 530 V on analog outputs

RFI and Interference Tests

5.5.1.2

EMC Immunity

Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 60255-22-3:2007 IEC 61000-4-3:2002, 10 V/m IEEE C37.90.2-1995, 35 V/m
Fast Transient, Burst Immunity:	IEC 60255-22-4:2008 IEC 61000-4-4:2004 4 kV @ 2.5 kHz 2 kV @ 5.0 kHz for comm. ports
Surge Immunity:	IEC 60255-22-5:2008 IEC 61000-4-5:2005 2 kV line-to-line 4 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 60255-22-1:1988 2.5 kV common mode 1.0 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient
Conducted RF Immunity:	IEC 60255-22-6:2001 IEC 61000-4-6:2006, 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2001 1000 A/m for 3 seconds 100 A/m for 1 minute

5.5.2.2

SEL-700G Data Sheet

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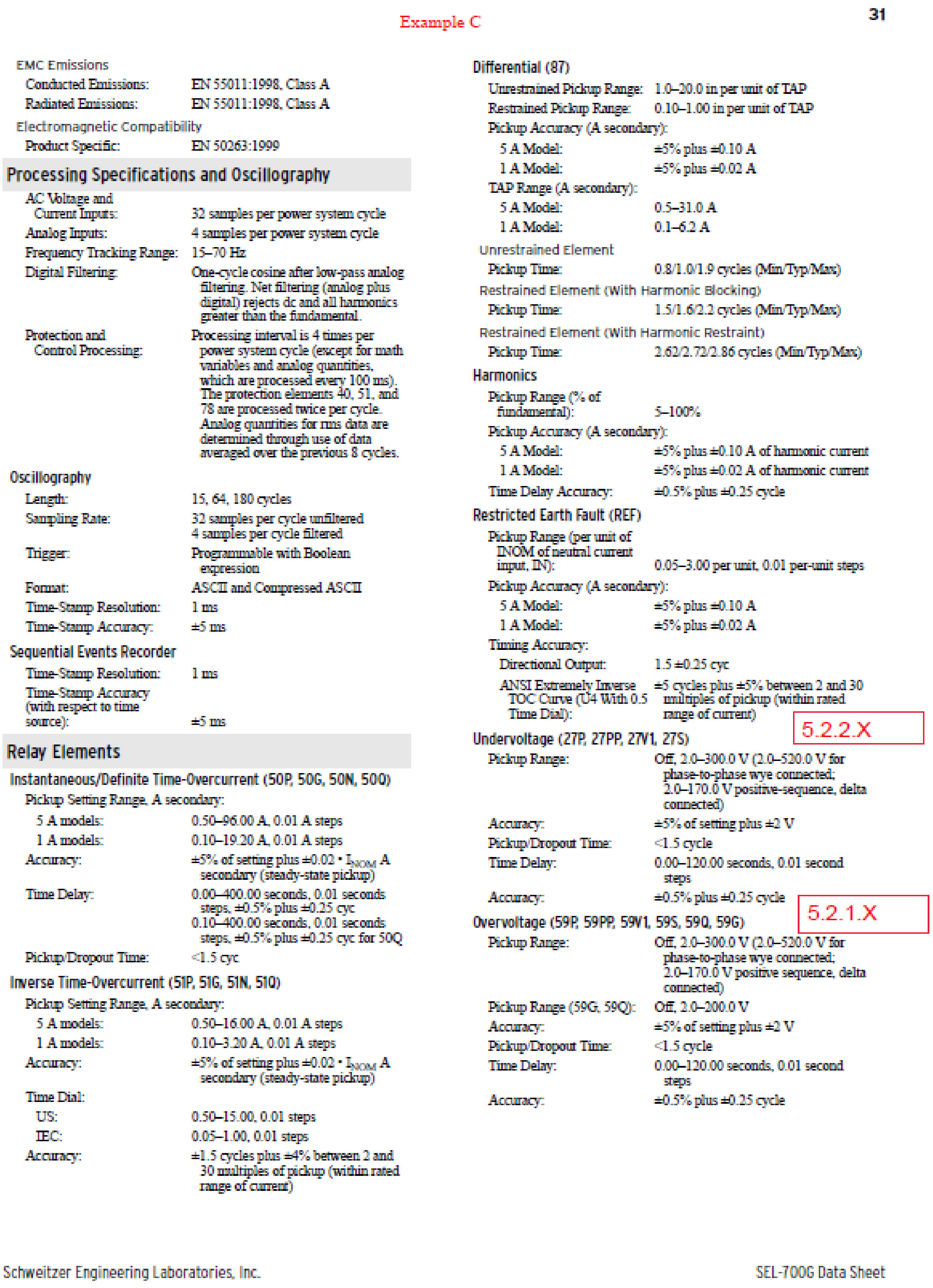
Appendix 3



Example C

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EMC Emissions

Conducted Emissions:	EN 55011:1998, Class A
Radiated Emissions:	EN 55011:1998, Class A

Electromagnetic Compatibility

Product Specific:	EN 50263:1999

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	32 samples per power system cycle
Analog Inputs:	4 samples per power system cycle
Frequency Tracking Range:	15–70 Hz
Digital Filtering:	One-cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
Protection and Control Processing:	Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 100 ms). The protection elements 40, 51, and 78 are processed twice per cycle. Analog quantities for rms data are determined through use of data averaged over the previous 8 cycles.

Oscillography

Length:	15, 64, 180 cycles
Sampling Rate:	32 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII
Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy:	±5 ms

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (with respect to time source):	±5 ms

Relay Elements

Instantaneous/Definite Time-Overcurrent (50P, 50G, 50N, 50Q)

Pickup Setting Range, A secondary:	
5 A models:	0.50–96.00 A, 0.01 A steps
1 A models:	0.10–19.20 A, 0.01 A steps
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (steady-state pickup)
Time Delay:	0.00–400.00 seconds, 0.01 seconds steps, ±0.5% plus ±0.25 cyc 0.10–400.00 seconds, 0.01 seconds steps, ±0.5% plus ±0.25 cyc for 50Q
Pickup/Dropout Time:	<1.5 cyc

Inverse Time-Overcurrent (51P, 51G, 51N, 51Q)

Pickup Setting Range, A secondary:	
5 A models:	0.50–16.00 A, 0.01 A steps
1 A models:	0.10–3.20 A, 0.01 A steps
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (steady-state pickup)
Time Dial:	
US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Accuracy:	±1.5 cycles plus ±4% between 2 and 30 multiples of pickup (within rated range of current)

Differential (87)

Unrestrained Pickup Range:	1.0–20.0 in per unit of TAP
Restrained Pickup Range:	0.10–1.00 in per unit of TAP
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
TAP Range (A secondary):	
5 A Model:	0.5–31.0 A
1 A Model:	0.1–6.2 A

Unrestrained Element

Pickup Time:	0.8/1.0/1.9 cycles (Min/Typ/Max)

Restrained Element (With Harmonic Blocking)

Pickup Time:	1.5/1.6/2.2 cycles (Min/Typ/Max)

Restrained Element (With Harmonic Restraint)

Pickup Time:	2.62/2.72/2.86 cycles (Min/Typ/Max)

Harmonics

Pickup Range (% of fundamental):	5–100%
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A of harmonic current
1 A Model:	±5% plus ±0.02 A of harmonic current
Time Delay Accuracy:	±0.5% plus ±0.25 cycle

Restricted Earth Fault (REF)

Pickup Range (per unit of INOM of neutral current input, IN):	0.05–3.00 per unit, 0.01 per-unit steps
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Timing Accuracy:	
Directional Output:	1.5 ±0.25 cyc
ANSI Extremely Inverse TOC Curve (U4 With 0.5 Time Dial):	±5 cycles plus ±5% between 2 and 30 multiples of pickup (within rated range of current)

5.2.2.X

Undervoltage (27P, 27PP, 27V1, 27S)

Pickup Range:	Off, 2.0–300.0 V (2.0–520.0 V for phase-to-phase wye connected; 2.0–170.0 V positive-sequence, delta connected)
Accuracy:	±5% of setting plus ±2 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

5.2.1.X

Overvoltage (59P, 59PP, 59V1, 59S, 59Q, 59G)

Pickup Range:	Off, 2.0–300.0 V (2.0–520.0 V for phase-to-phase wye connected; 2.0–170.0 V positive sequence, delta connected)
Pickup Range (59G, 59Q):	Off, 2.0–200.0 V
Accuracy:	±5% of setting plus ±2 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

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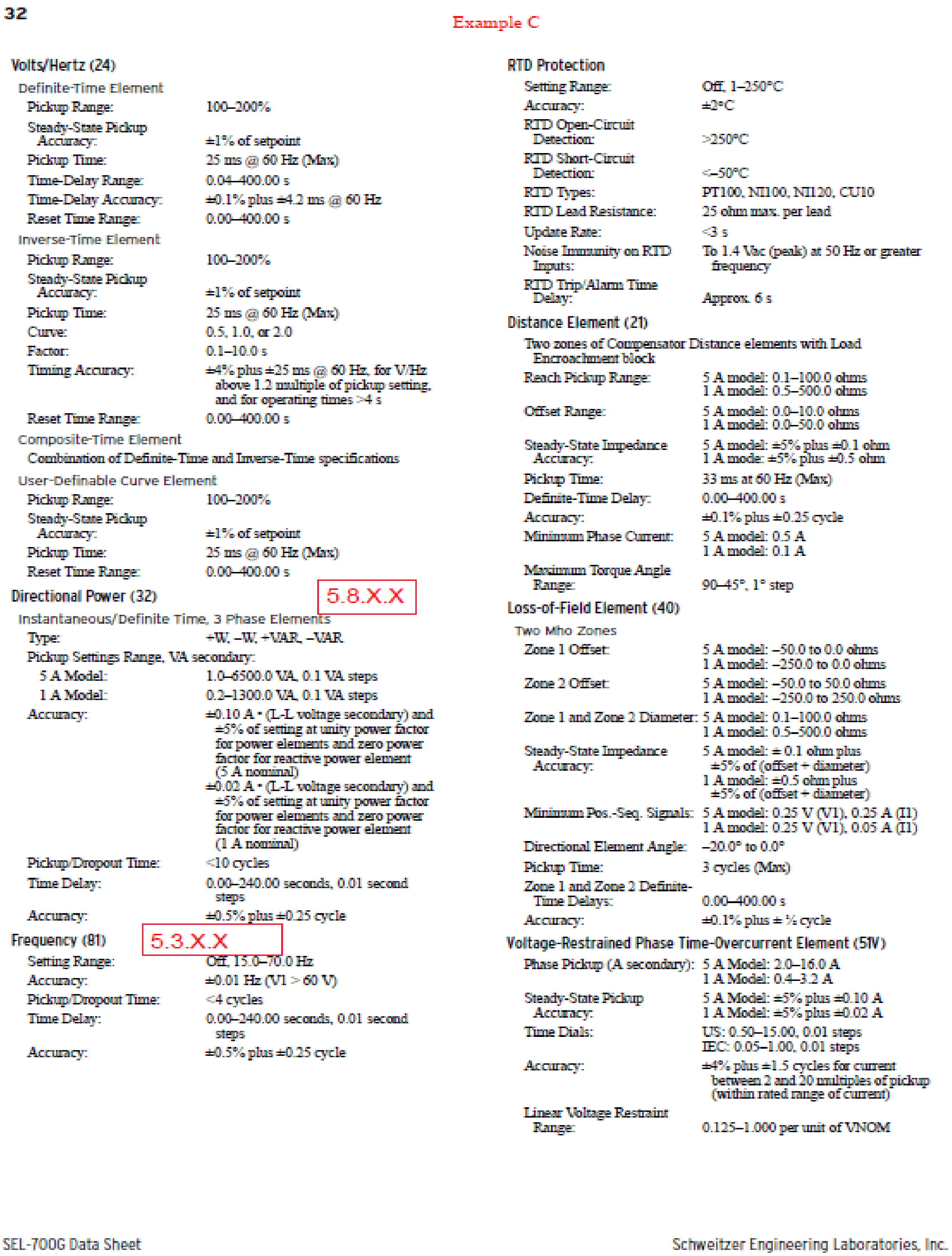
SEL-700G Data Sheet

Appendix 3



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Example C

Volts/Hertz (24)

Definite-Time Element

Pickup Range:	100–200%
Steady-State Pickup Accuracy:	±1% of setpoint
Pickup Time:	25 ms @ 60 Hz (Max)
Time-Delay Range:	0.04–400.00 s
Time-Delay Accuracy:	±0.1% plus ±4.2 ms @ 60 Hz
Reset Time Range:	0.00–400.00 s

Inverse-Time Element

Pickup Range:	100–200%
Steady-State Pickup Accuracy:	±1% of setpoint
Pickup Time:	25 ms @ 60 Hz (Max)
Curve:	0.5, 1.0, or 2.0
Factor:	0.1–10.0 s
Timing Accuracy:	±4% plus ±25 ms @ 60 Hz, for V/Hz above 1.2 multiple of pickup setting, and for operating times >4 s
Reset Time Range:	0.00–400.00 s

Composite-Time Element

Combination of Definite-Time and Inverse-Time specifications

User-Definable Curve Element

Pickup Range:	100–200%
Steady-State Pickup Accuracy:	±1% of setpoint
Pickup Time:	25 ms @ 60 Hz (Max)
Reset Time Range:	0.00–400.00 s

Directional Power (32)

5.8.X.X

Instantaneous/Definite Time, 3 Phase Elements

Type:	+W, –W, +VAR, –VAR
Pickup Settings Range, VA secondary:	
5 A Model:	1.0–6500.0 VA, 0.1 VA steps
1 A Model:	0.2–1300.0 VA, 0.1 VA steps
Accuracy:	±0.10 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.02 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)
Pickup/Dropout Time:	<10 cycles
Time Delay:	0.00–240.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

Frequency (81)

5.3.X.X

Setting Range:	Off, 15.0–70.0 Hz
Accuracy:	±0.01 Hz (V1 > 60 V)
Pickup/Dropout Time:	<4 cycles
Time Delay:	0.00–240.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

RTD Protection

Setting Range:	Off, 1–250°C
Accuracy:	±2°C
RTD Open-Circuit Detection:	>250°C
RTD Short-Circuit Detection:	<–50°C
RTD Types:	PT100, NI100, NI120, CU10
RTD Lead Resistance:	25 ohm max. per lead
Update Rate:	<3 s
Noise Immunity on RTD Inputs:	To 1.4 Vac (peak) at 50 Hz or greater frequency
RTD Trip/Alarm Time Delay:	Approx. 6 s

Distance Element (21)

Two zones of Compensator Distance elements with Load Encroachment block

Reach Pickup Range:	5 A model: 0.1–100.0 ohms 1 A model: 0.5–500.0 ohms
Offset Range:	5 A model: 0.0–10.0 ohms 1 A model: 0.0–50.0 ohms
Steady-State Impedance Accuracy:	5 A model: ±5% plus ±0.1 ohm 1 A mode: ±5% plus ±0.5 ohm
Pickup Time:	33 ms at 60 Hz (Max)
Definite-Time Delay:	0.00–400.00 s
Accuracy:	±0.1% plus ±0.25 cycle
Minimum Phase Current:	5 A model: 0.5 A 1 A model: 0.1 A
Maximum Torque Angle Range:	90–45°, 1° step

Loss-of-Field Element (40)

Two Mho Zones

Zone 1 Offset:	5 A model: –50.0 to 0.0 ohms 1 A model: –250.0 to 0.0 ohms
Zone 2 Offset:	5 A model: –50.0 to 50.0 ohms 1 A model: –250.0 to 250.0 ohms
Zone 1 and Zone 2 Diameter:	5 A model: 0.1–100.0 ohms 1 A model: 0.5–500.0 ohms
Steady-State Impedance Accuracy:	5 A model: ± 0.1 ohm plus ±5% of (offset + diameter) 1 A model: ±0.5 ohm plus ±5% of (offset + diameter)
Minimum Pos.-Seq. Signals:	5 A model: 0.25 V (V1), 0.25 A (I1) 1 A model: 0.25 V (V1), 0.05 A (I1)
Directional Element Angle:	–20.0° to 0.0°
Pickup Time:	3 cycles (Max)
Zone 1 and Zone 2 Definite-Time Delays:	0.00–400.00 s
Accuracy:	±0.1% plus ± ½ cycle

Voltage-Restrained Phase Time-Overcurrent Element (51V)

Phase Pickup (A secondary):	5 A Model: 2.0–16.0 A 1 A Model: 0.4–3.2 A
Steady-State Pickup Accuracy:	5 A Model: ±5% plus ±0.10 A 1 A Model: ±5% plus ±0.02 A
Time Dials:	US: 0.50–15.00, 0.01 steps IEC: 0.05–1.00, 0.01 steps
Accuracy:	±4% plus ±1.5 cycles for current between 2 and 20 multiples of pickup (within rated range of current)
Linear Voltage Restraint Range:	0.125–1.000 per unit of VNOM

SEL-700G Data Sheet

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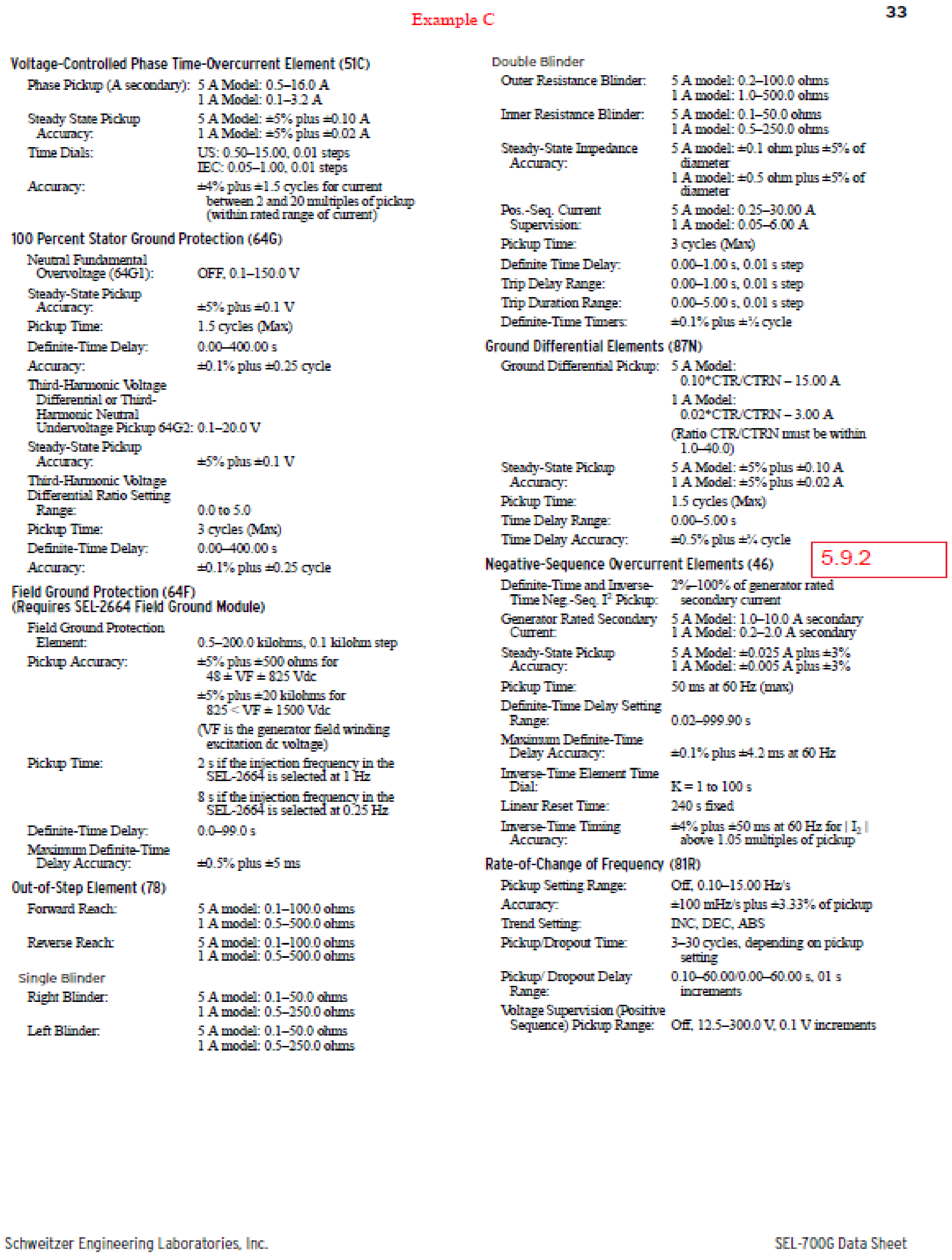
Appendix 3



Example C

Voltage-Controlled Phase Time-Overcurrent Element (51C)

Phase Pickup (A secondary):	5 A Model: 0.5–16.0 A 1 A Model: 0.1–3.2 A
Steady State Pickup Accuracy:	5 A Model: ±5% plus ±0.10 A 1 A Model: ±5% plus ±0.02 A
Time Dials:	US: 0.50–15.00, 0.01 steps IEC: 0.05–1.00, 0.01 steps
Accuracy:	±4% plus ±1.5 cycles for current between 2 and 20 multiples of pickup (within rated range of current)

100 Percent Stator Ground Protection (64G)

Neutral Fundamental Overvoltage (64G1):	OFF, 0.1–150.0 V
Steady-State Pickup Accuracy:	±5% plus ±0.1 V
Pickup Time:	1.5 cycles (Max)
Definite-Time Delay:	0.00–400.00 s
Accuracy:	±0.1% plus ±0.25 cycle
Third-Harmonic Voltage Differential or Third-Harmonic Neutral Undervoltage Pickup 64G2:	0.1–20.0 V
Steady-State Pickup Accuracy:	±5% plus ±0.1 V
Third-Harmonic Voltage Differential Ratio Setting Range:	0.0 to 5.0
Pickup Time:	3 cycles (Max)
Definite-Time Delay:	0.00–400.00 s
Accuracy:	±0.1% plus ±0.25 cycle

Field Ground Protection (64F) (Requires SEL-2664 Field Ground Module)

Field Ground Protection Element:	0.5–200.0 kilohms, 0.1 kilohm step
Pickup Accuracy:	±5% plus ±500 ohms for 48 ≤ VF ≤ 825 Vdc ±5% plus ±20 kilohms for 825 < VF ≤ 1500 Vdc (VF is the generator field winding excitation dc voltage)
Pickup Time:	2 s if the injection frequency in the SEL-2664 is selected at 1 Hz 8 s if the injection frequency in the SEL-2664 is selected at 0.25 Hz
Definite-Time Delay:	0.0–99.0 s
Maximum Definite-Time Delay Accuracy:	±0.5% plus ±5 ms

Out-of-Step Element (78)

Forward Reach:	5 A model: 0.1–100.0 ohms 1 A model: 0.5–500.0 ohms
Reverse Reach:	5 A model: 0.1–100.0 ohms 1 A model: 0.5–500.0 ohms

Single Blinder

Right Blinder:	5 A model: 0.1–50.0 ohms 1 A model: 0.5–250.0 ohms
Left Blinder:	5 A model: 0.1–50.0 ohms 1 A model: 0.5–250.0 ohms

Double Blinder

Outer Resistance Blinder:	5 A model: 0.2–100.0 ohms 1 A model: 1.0–500.0 ohms
Inner Resistance Blinder:	5 A model: 0.1–50.0 ohms 1 A model: 0.5–250.0 ohms
Steady-State Impedance Accuracy:	5 A model: ±0.1 ohm plus ±5% of diameter 1 A model: ±0.5 ohm plus ±5% of diameter
Pos.-Seq. Current Supervision:	5 A model: 0.25–30.00 A 1 A model: 0.05–6.00 A
Pickup Time:	3 cycles (Max)
Definite Time Delay:	0.00–1.00 s, 0.01 s step
Trip Delay Range:	0.00–1.00 s, 0.01 s step
Trip Duration Range:	0.00–5.00 s, 0.01 s step
Definite-Time Timers:	±0.1% plus ±¼ cycle

Ground Differential Elements (87N)

Ground Differential Pickup:	5 A Model: 0.10*CTR/CTRN – 15.00 A 1 A Model: 0.02*CTR/CTRN – 3.00 A (Ratio CTR/CTRN must be within 1.0–40.0)
Steady-State Pickup Accuracy:	5 A Model: ±5% plus ±0.10 A 1 A Model: ±5% plus ±0.02 A
Pickup Time:	1.5 cycles (Max)
Time Delay Range:	0.00–5.00 s
Time Delay Accuracy:	±0.5% plus ±¼ cycle

5.9.2

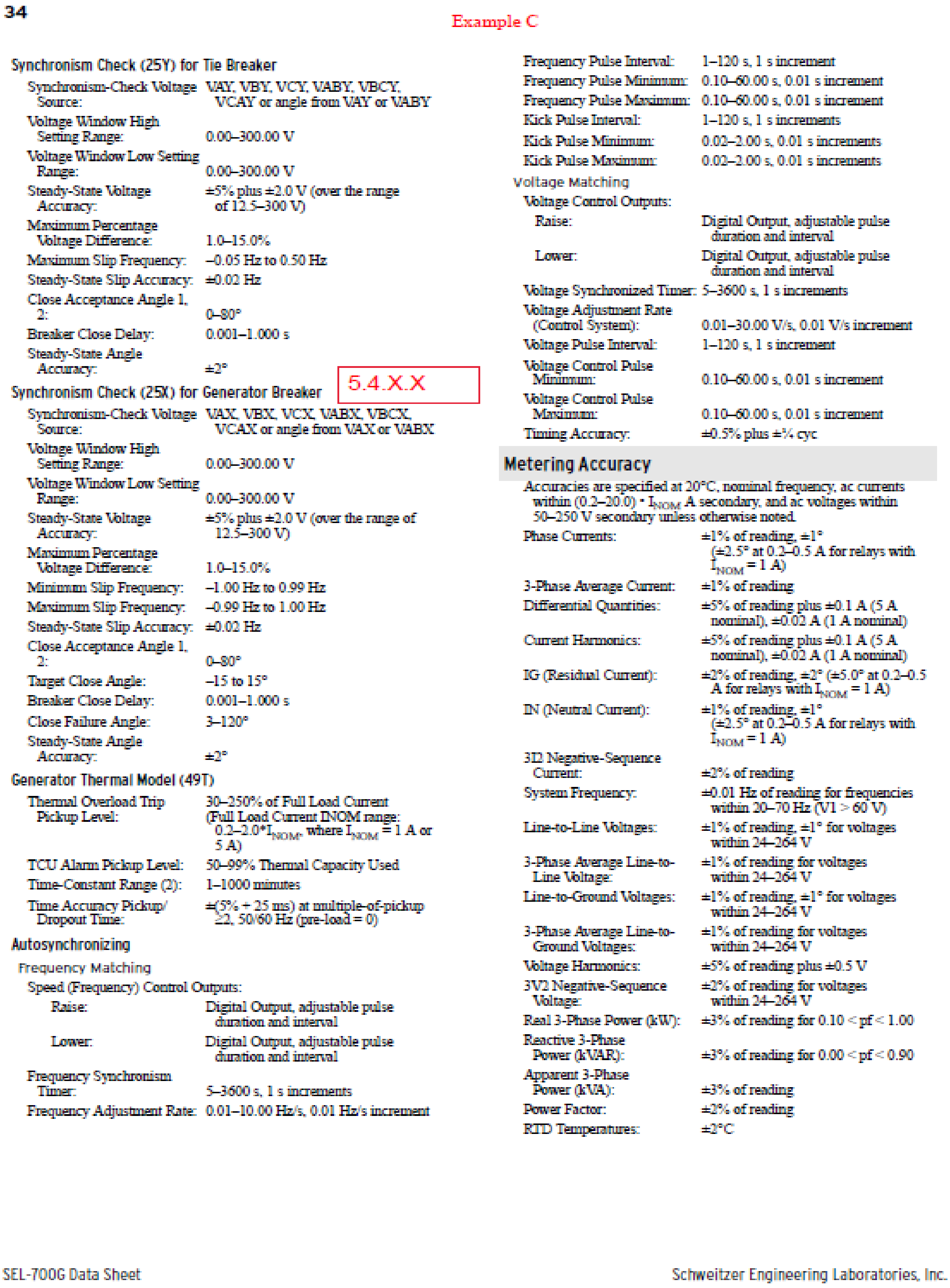
Negative-Sequence Overcurrent Elements (46)

Definite-Time and Inverse-Time Neg.-Seq. I^2 Pickup:	2%–100% of generator rated secondary current
Generator Rated Secondary Current:	5 A Model: 1.0–10.0 A secondary 1 A Model: 0.2–2.0 A secondary
Steady-State Pickup Accuracy:	5 A Model: ±0.025 A plus ±3% 1 A Model: ±0.005 A plus ±3%
Pickup Time:	50 ms at 60 Hz (max)
Definite-Time Delay Setting Range:	0.02–999.90 s
Maximum Definite-Time Delay Accuracy:	±0.1% plus ±4.2 ms at 60 Hz
Inverse-Time Element Time Dial:	K = 1 to 100 s
Linear Reset Time:	240 s fixed
Inverse-Time Timing Accuracy:	±4% plus ±50 ms at 60 Hz for $\mid I_2 \mid$ above 1.05 multiples of pickup

Rate-of-Change of Frequency (81R)

Pickup Setting Range:	Off, 0.10–15.00 Hz/s
Accuracy:	±100 mHz/s plus ±3.33% of pickup
Trend Setting:	INC, DEC, ABS
Pickup/Dropout Time:	3–30 cycles, depending on pickup setting
Pickup/ Dropout Delay Range:	0.10–60.00/0.00–60.00 s, 01 s increments
Voltage Supervision (Positive Sequence) Pickup Range:	Off, 12.5–300.0 V, 0.1 V increments

Appendix 3



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Example C

Synchronism Check (25Y) for Tie Breaker

Synchronism-Check Voltage Source:	VAY, VBY, VCY, VABY, VBCY, VCAY or angle from VAY or VABY
Voltage Window High Setting Range:	0.00–300.00 V
Voltage Window Low Setting Range:	0.00–300.00 V
Steady-State Voltage Accuracy:	±5% plus ±2.0 V (over the range of 12.5–300 V)
Maximum Percentage Voltage Difference:	1.0–15.0%
Maximum Slip Frequency:	–0.05 Hz to 0.50 Hz
Steady-State Slip Accuracy:	±0.02 Hz
Close Acceptance Angle 1, 2:	0–80°
Breaker Close Delay:	0.001–1.000 s
Steady-State Angle Accuracy:	±2°

5.4.X.X

Synchronism Check (25X) for Generator Breaker

Synchronism-Check Voltage Source:	VAX, VBX, VCX, VABX, VBCX, VCAX or angle from VAX or VABX
Voltage Window High Setting Range:	0.00–300.00 V
Voltage Window Low Setting Range:	0.00–300.00 V
Steady-State Voltage Accuracy:	±5% plus ±2.0 V (over the range of 12.5–300 V)
Maximum Percentage Voltage Difference:	1.0–15.0%
Minimum Slip Frequency:	–1.00 Hz to 0.99 Hz
Maximum Slip Frequency:	–0.99 Hz to 1.00 Hz
Steady-State Slip Accuracy:	±0.02 Hz
Close Acceptance Angle 1, 2:	0–80°
Target Close Angle:	–15 to 15°
Breaker Close Delay:	0.001–1.000 s
Close Failure Angle:	3–120°
Steady-State Angle Accuracy:	±2°

Generator Thermal Model (49T)

Thermal Overload Trip Pickup Level:	30–250% of Full Load Current (Full Load Current INOM range: 0.2–2.0*I_{NOM}, where I_{NOM} = 1 A or 5 A)
TCU Alarm Pickup Level:	50–99% Thermal Capacity Used
Time-Constant Range (2):	1–1000 minutes
Time Accuracy Pickup/Dropout Time:	±(5% + 25 ms) at multiple-of-pickup ≥2, 50/60 Hz (pre-load = 0)

Autosynchronizing

Frequency Matching

Speed (Frequency) Control Outputs:	
Raise:	Digital Output, adjustable pulse duration and interval
Lower:	Digital Output, adjustable pulse duration and interval
Frequency Synchronism Timer:	5–3600 s, 1 s increments
Frequency Adjustment Rate:	0.01–10.00 Hz/s, 0.01 Hz/s increment
Frequency Pulse Interval:	1–120 s, 1 s increment
Frequency Pulse Minimum:	0.10–60.00 s, 0.01 s increment
Frequency Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Kick Pulse Interval:	1–120 s, 1 s increments
Kick Pulse Minimum:	0.02–2.00 s, 0.01 s increments
Kick Pulse Maximum:	0.02–2.00 s, 0.01 s increments

Voltage Matching

Voltage Control Outputs:	
Raise:	Digital Output, adjustable pulse duration and interval
Lower:	Digital Output, adjustable pulse duration and interval
Voltage Synchronized Timer:	5–3600 s, 1 s increments
Voltage Adjustment Rate (Control System):	0.01–30.00 V/s, 0.01 V/s increment
Voltage Pulse Interval:	1–120 s, 1 s increment
Voltage Control Pulse Minimum:	0.10–60.00 s, 0.01 s increment
Voltage Control Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Timing Accuracy:	±0.5% plus ±¼ cyc

Metering Accuracy

Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • I_{NOM} A secondary, and ac voltages within 50–250 V secondary unless otherwise noted.

Phase Currents:	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
3-Phase Average Current:	±1% of reading
Differential Quantities:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
Current Harmonics:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
IG (Residual Current):	±2% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
IN (Neutral Current):	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
3I2 Negative-Sequence Current:	±2% of reading
System Frequency:	±0.01 Hz of reading for frequencies within 20–70 Hz (V1 > 60 V)
Line-to-Line Voltages:	±1% of reading, ±1° for voltages within 24–264 V
3-Phase Average Line-to-Line Voltage:	±1% of reading for voltages within 24–264 V
Line-to-Ground Voltages:	±1% of reading, ±1° for voltages within 24–264 V
3-Phase Average Line-to-Ground Voltages:	±1% of reading for voltages within 24–264 V
Voltage Harmonics:	±5% of reading plus ±0.5 V
3V2 Negative-Sequence Voltage:	±2% of reading for voltages within 24–264 V
Real 3-Phase Power (kW):	±3% of reading for 0.10 < pf < 1.00
Reactive 3-Phase Power (kVAR):	±3% of reading for 0.00 < pf < 0.90
Apparent 3-Phase Power (kVA):	±3% of reading
Power Factor:	±2% of reading
RTD Temperatures:	±2°C

SEL-700G Data Sheet Schweitzer Engineering Laboratories, Inc.

Appendix 3

Example D

DISTRIBUTED GENERATION IEEE 1547.1 TESTING DOCUMENTATION INDEX

Facility Name:
Facility Location:
Total Generation:
DG Type:
Date:

ID	Document
A	Brand XYZ, Model 123 Converter Test (IEC XXXXX-XX)
B	Brand ABC, Model 456 Turbine Type Test – Design Evaluation
C	Brand ABC, Model 456 Turbine Type Test – Annex to Design
D	Brand XYZ, Model 123 Converter Test (UL XXXX)
E	Brand DEF Relay Manufacturer Specification
F	Brand DEF Relay Test Report
G	Brand ABC Turbine Technical Specifications
H	Previous Transformer Inrush Test Result
I	Brand GHI Breaker Specifications

Line	Testing Notes
1	All field tests shall be conducted per IEEE 1547.1 procedures in referenced section
2	General requirements contained in IEEE 1547.1, Section 4 apply to field tests
3	Field tests conducted on complete commissioned facility to Area EPS
4	All field test data recording and instrumentation shall be controlled by the testing entity
5	Facility technicians will operate facility for purpose of field tests
6	More notes
7	More notes
8	More notes
9	And more notes
10	
11	
12	