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 generator/customer 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 generator/customer 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 generator/customer'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 an performs an impact study in response to an application for interconnection of generation equipment 20 megawatts or less (standard form application) the generator/customer may need to test the interconnection system (ICS) to assure IEEE 1547 compliance. It is the generator/customer's responsibility to clearly communicate its testing proposal and test result report to AEP. The contents of this guide will help the generator/customer 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 generator/customer 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 report 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 report 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 in appendix D)
        ii. An ***Over-voltage Timing*** Type test would be titled with **5.2.1.3 Over-voltage Timing test results**. (See example in appendix D)

iii. A ***Synchronization*** Production test result would be titled with **6.3 Synchronization test results**. (follow same format as appendix D)

iv. A ***Revised settings*** Commissioning test result would be titled with **7.6 Revised Settings test results**. (follow same format as appendix D)

b. Unless the test purpose or procedure outlined in each sub-article is modified, the test report 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 submitted test report. (See examples in Appendix B)

c. Appendix 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. It includes populated examples.

4. Article 5, Type tests

a. It is the responsibility of the generator/customer 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 examples in Appendix C)

5. Article 6, Production tests

a. It is the responsibility of the generator/customer 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 examples in Appendix 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 generator/customer test procedure can simply be a list of the sub-article numbers of the Type, Production, and Commissioning tests that will be conducted by the generator/customer. 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 generator/customer submitted test procedure. (See examples in Appendix 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 examples in Appendix C)

7. Article 8, Periodic interconnection tests

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

Appendixes:

1. Appendix A – testing documentation - is a suggested cover sheet format for the customer's IEEE 1547.1 test results report package. It is partially populated with examples of the support documents the customer plans to supply to support their claim of IEEE 1547 compliance.
2. Appendix B – testing matrix - is a suggested format that enables the customer to present how they plan to comply with a particular IEEE 1547.1 test and indicate the devices, documents, and notes that relate to a given test. The second and third pages are partially populated examples with representative typical content.
3. Appendix C – type and production test result identification example - are examples of how a manufacturer's own testing specifications can be used and highlighted to clearly indicate where and what IEEE 1547.1 test requirement is fulfilled in support of the type or production tests.
4. Appendix D – testing results summary example - is a suggested format that AEP prefers for reporting customer - third party test results while complying with IEEE 1547.1 test result reporting requirements. Typical data included for illustrative purposes.

Appendix A

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	

Appendix B

DISTRIBUTED GENERATION IEEE 1547.1 TESTING MATRIX

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

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						
2	5.1.2.2	Storage Temperature						
3	5.2.1.2	Overvoltage - Magnitude						
4	5.2.1.3	Overvoltage - Trip Time						
5	5.2.2.2	Undervoltage - Magnitude						
6	5.2.2.3	Undervoltage - Trip Time						
7	5.3.1.2	Overfrequency - Magnitude						
8	5.3.1.3	Overfrequency - Trip Time						
9	5.3.2.2	Underfrequency - Magnitude						
10	5.3.2.3	Underfrequency - Trip Time						
11	5.4.1.2	Synchronization - Method 1 - Variation 1						
12	5.4.2.2	Synchronization - Method 1 - Variation 2						
13	5.4.3.2	Synchronization - Method 1 - Variation 3						
14	5.4.4.2	Startup Current - Method 2						
15	5.5.1.2	Protection from Electromagnetic Interference						
16	5.5.2.2	Surge withstand Performance						
17	5.5.3.2	Dielectric Test of Paralleling Device						
18	5.6.2	Limitation of DC Injection (Inverters without XFMR)						
19	5.7.1.2	Unintentional Islanding Test						
20	5.7.2.2	Unintentional Islanding Test for Synchronous Generators						
21	5.8.1.2	Reverse-Power (for unintentional islanding)						
22	5.8.2.2	Reverse-Power Time Test						
23	5.9.2	Open Phase						
24	5.10.2	Reconnect Following Abnormal Condition Disconnect						
25	5.11.1.1	Harmonics						
26	5.11.2.1	Harmonics for Synchronous Generators						
27	5.11.3.1	Harmonics for Induction Generators						
28	6.1.2	Response to Abnormal Voltage						
29	6.2.2	Response to Abnormal Frequency						
30	6.3.1.1	Synchronization Production						
31	6.3.2.1	Optional Test for Equipment with Synchronizing Disable						
32	7.2	Verifications and Inspections						
33	7.4.1	Reverse-Power or Minimum Power Test						
34	7.4.2	Non-Islanding Functionality Test						
35	7.4.3	Other Unintentional Islanding Test						
36	7.5.1	Cease-to-Energize Functionality						

Appendix B

Distrbuted Generation Facility IEEE 1547.1 Testing Matrix

Facility Name
Facility Location
Total Generation

DG Type
Date

Line	IEEE 1547.1 ID	IEEE 1547.1 Test	Type/Production Test	Field Test	Not Applicable	Device under test	Referenced Document	Notes
1	5.1.2.1	Operational Temperature Test						
2	5.1.2.2	Storage Temperature Test						
3	5.2.1.2	Test for overvoltage magnitude		X		SEL351A relay	D	Per IEEE 1547.1 test procedure
4	5.2.1.3	Test for overvoltage trip time		X		SEL351A relay	D	Per IEEE 1547.1 test procedure
5	5.2.2.2	Test for undervoltage magnitude		X		SEL351A relay	D	Per IEEE 1547.1 test procedure
6	5.2.2.3	Test for undervoltage trip time		X		SEL351A relay	D	Per IEEE 1547.1 test procedure
7	5.3.1.2	Test for overfrequency magnitude	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
8	5.3.1.3	Test for overfrequency trip time	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
9	5.3.2.2	Test for underfrequency magnitude	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
10	5.3.2.3	Test for underfrequency trip time	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
11	5.4.1.2	Synchronization Method 1 Variation 1						
12	5.4.2.2	Synchronization Method 1 Variation 2						
13	5.4.3.2	Synchronization Method 1 Variation 3						
14	5.4.4.2	Synchronization Startup current measurement (Method 2)						
15	5.5.1.2	Protection from electromagnetic interference (EMI) test	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
16	5.5.2.2	Surge withstand performance test	X			SEL351A relay	C	Per supplied manufacturer's spec sheet
17	5.5.3.2	Dielectric test for paralleling device						
18	5.6.2	Limitation of dc injection for inverters without interconnection transformers						
19	5.7.1.2	Unintentional Islanding test						
20	5.7.2.2	Unintentional Islanding test for synchronous generators		X		SEL351A relay	D	Per IEEE 1547.1 test procedure/Document D will
21	5.8.1.2	Reverse power for unintentional islanding						
22	5.8.2.2	Reverse power time test						
23	5.9.2	Open phase test						
24	5.10.2	Reconnect following abnormal condition disconnect test						
25	5.11.1.1	Harmonics test for inverters			X			Synchrounous Machine
26	5.11.2.1	Harmonics test for synchronous generators	X				B	Synchrounous Machine spec sheet
27	5.11.3.1	Harmonics test for induction generators						
28	6.1.2	Response to abnormal voltage						
29	6.2.2	Response to abnormal frequency						
30	6.3.1.1	Synchronization production test						
31	6.3.2.1	Optional test for equipment with synchronizing disable function						
32	7.2	Verifications and inspections		X		Entire DG system	D	Per IEEE 1547.1 test procedure/Document D will
33	7.4.1	Reverse power or minimum power test		X		SEL351A relay	D	Per IEEE 1547.1 test procedure/Document D will
34	7.4.2	Non-island functionality test						
35	7.4.3	Other unintentional islanding test methods						
36	7.5.1	Cease to energize functionality test						

Appendix 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 C

SEL 351A Manufacturer Specifications

Specifications

Important: Do not use the following specification information to order an SEL 351A. Refer to the actual ordering information sheets.

General

Terminal Connections

Note Terminals or stranded copper \ ıre Rıng termınal are recommended Mınımum temperature ratıng of I

Tightening Torque, Terminal Blo k

Mınimum	8 ın-lb (9 Nm
Maximum	12 in lb (1 4 Nm)

Tightening Torque, Connectorized

Mınımum	4 4 ın-l (5 Nm
Maximum	8 8 ın-lb (1 0 Nm)

AC Voltage Inputs

300 V_{L-N} continuous lımıt for three-pha four-wıre wye conn ctıon

300 V_{L-L} contınuous lımıt for three-phase, three-wıre delta connectıon (connect any voltage up to 300 Vac)

600 Vac for 10 seconds

Burden	0 03 VA at 67 V 0 06 VA at 120 V 0 80 VA at 300 V

AC Current Inputs

Nominal	5 A
Continuous	15 A
1 Second Thermal	500 A lınear to 100 A symmetrıcal 1250 A for 1 cycle
Burden	0 27 VA at 5 A 2 51 VA at 15 A
Nominal	1 A
Contınuous	3 A
1 Second Thermal	100 A lınear to 20 A symmetrıcal 250 A for 1 cycle
Burden	0 13 VA at 1 A, 1 31 VA at 3 A

Additional Neutral Channel IN Options (Not in SEL-351A-1)

Nominal	0 2 A
Continuous	15 A
1 Second Thermal	500 A lınear to 5 5 A symmetrıcal 1250 A for 1 cycle
Burden	0 002 VA at 0 2 A, 1 28 VA at 15 A
Nominal	0 05 A
Continuous	1 5 A
1 Second Thermal	20 A lınear to 1 5 A symmetrıcal 100 A for 1 cycle
Burden	0 0004 VA at 0.05 A, 0 36 VA at 1 5 A

Note: The 0 05 A option ıs a legacy nondırectıonal SEF protectıon optıon The 0 2 A option provides nondırectıonal SEF protectıon plus dırectıonal protection for various system groundıng practıces

Power Supply

125/250 Vd or Va

Range	85 350 Vdc or 85 264 Vac (50 60 Hz)
Burden	25 W

48/125 Vdc or 125 Vac

Range	38 200 Vdc or 85 140 Vac (50 60 Hz)
Burden	25 W

24/48 Vdc

Range	18 60 Vdc
Burden	25 W

Frequency and Rotation

S st m Frequency	60 or 50 Hz
Pha e Rotation	ABC or ACB
Frequency Tracking Range	40 1 65 Hz

Note: V_A or V_1 requıred for frequency trackıng

Control Outputs

Standard

Make	30 A
Carry	6 A contınuous carry at 70 C 4 A contınuous carry at 85 C
1s Ratıng	50 A
MOV Protection	270 Vac 360 Vdc, 40 J
Pickup Tıme	5 ms

Breakıng Capacity (10000 operations)

24 V	0.75 A	L/R	40 ms
48 V	0 50 A	L/R	40 ms
125 V	0 30 A	L/R	40 ms
250 V	0 20 A	L/R	40 ms

Cyclıc Capacıty (2 5 cycles second)

24 V	0.75 A	L/R	40 ms
48 V	0 50 A	L/R	40 ms
125 V	0 30 A	L/R	40 ms
250 V	0 20 A	L/R	40 ms

Note: Make rating per IEEE C37 90-1989

Optoisolated Inputs

When Used With DC Control Signals

250 Vdc	on for 200 300 Vdc,	off below 150 Vdc
220 Vdc	on for 176 264 Vdc,	off below 132 Vdc
125 Vdc	on for 105 150 Vdc,	off below 75 Vdc
110 Vdc	on for 88 132 Vdc,	off below 66 Vdc
48 Vdc	on for 38 4 60 Vdc,	off below 28 8 Vdc
24 Vdc	on for 15 30 Vdc	

When Used With AC Control Signals

250 Vdc	on for 170 6 300 Vac,	off below 106 0 Vac
220 Vdc	on for 150 3 264 0 Vac,	off below 93 2 Vac
125 Vdc:	on for 89.6 150 0 Vac,	off below 53 0 Vac
110 Vdc	on for 75 1 132 0 Vac,	off below 46 6 Vac
48 Vdc	on for 32 8 60 0 Vac,	off below 20 3 Vac
24 Vdc	on for 12 8 30 0 Vac	

Note: AC mode is selectable for each ınput via Global settıngs IN101D IN106D, AC input recognition delay from tıme of swit hın 0 75 cycles maximum pıckup, 1 25 cycles maxımum dropout
Note: 24, 48, 125, 220, and 250 Vdc optoısolated ınputs draw approximately 5 mA of current, 110 Vdc ınputs draw approxımately 8 mA of current All current ratıngs are at nomınal ınput voltage

Appendix C

Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Port 1 or 2.

Synchronization (specification is with respect to the accuracy of the time source):

Synchrophasor:	± 10 µs
Other:	± 5 ms

Communications Ports

EIA-232:	1 Front and 2 Rear
EIA-485:	1 Rear, 2100 Vdc of isolation
Data Speed:	300–38400 bps (38400 is not available on Port 1)

Dimensions

Refer to *Figure 20*.

Weight

13 lbs (5.92 kg)—2U rack unit height relay

Operating Temperature

–40° to +185°F (–40° to +85°C)
(LCD contrast impaired for temperatures below –20°C.)

Type Tests

5.5.1.2 ---> Electromagnetic Compatibility Immunity

Conducted RF Immunity:	IEC 60255-22-6:2001 Severity Level: 10 Vrms
Digital Radio Telephone RF Immunity:	ENV 50204:1995 Severity Level: 10 V/m at 900 MHz and 1.89 GHz
Electrostatic Discharge Immunity:	IEC 60255-22-2:1996 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air IEC 61000-4-2:1995 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:1992 Severity Level: 4 kV at 2.5 kHz and 5 kHz IEC 61000-4-4:1995 Severity Level: 4 kV, 2.5 kHz on power supply, 2 kV, 5 kHz on I/O, signal, data, and control lines IEC 801-4:1988 Severity Level: 4 (4 kV on power supply, 2 kV on I/O)
Power Supply Immunity:	IEC 60255-11:1979
Radiated Radio Frequency Immunity:	ENV 50140:1994 Severity Level: 10 V/m IEC 60255-22-3:1989 Severity Level: 10 V/m Exception: 4.3.2.2 Frequency sweep approximated with 200 frequency steps per octave IEC 801-3:1984 Severity Level: 10 V/m Exceptions: 9.1 Frequency sweep approximated with 200 frequency steps per octave
Surge Immunity:	IEC 60255-22-5:2002 Severity Level: 1 kV Line to Line, 2 kV Line to Earth
5.5.2.2 ---> Surge Withstand Capability Immunity:	IEC 60255-22-1:1988 Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode IEEE C37.90.1:1989 Severity Level: 3.0 kV oscillatory, 5.0 kV fast transient

Environmental

Cold:	IEC 60068-2-1:1990+A1:1993+A2:1994 Severity Level: 16 hours at –40°C
Damp Heat, Cyclic:	IEC 60068-2-30:1980 Exceptions: 6.3.3 Humidity not less than 94%, Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat:	IEC 60068-2-2:1974+A1:1993+A2:1994 Severity Level: 16 hours at +85°C
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 1 Endurance, Class 2 Response IEC 60255-21-2:1988 Severity Level: Class 1—Shock withstand, Bump, and Class 2—Shock Response IEC 60255-21-3:1993 Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength:	IEEE C37.90:1989 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type tested for 1 minute.
Impulse:	IEC 60255-5:1977 Severity Level: 0.5 Joule, 5 kV

Certifications

ISO: Relay is designed and manufactured to an ISO-9001 certified quality program.
UL/CSA: UL listed to the requirements of *UL 508; CSA C22.2, N.14 for Industrial Control Equipment*.
CE: CE Mark

Processing Specifications

AC Voltage and Current Inputs

16 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 560 Hz.

Digital Filtering

One-cycle full cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.

Protection and Control Processing

Four times per power system cycle.

Relay Element Pickup Ranges and Accuracies

Synchronism-Check Elements (25) (Not in SEL-351A-1)

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0–80°, 1° steps
Phase Angle Accuracy:	±4°

Appendix C

Instantaneous/Definite-Time Overcurrent Elements (50) (Definite-Time Elements not in SEL-351A-1)

Current Pickup (A Secondary)

5 A Nominal Phase Channels:	0.25–100.00 A, 0.01 A steps (phase & negative-sequence) 1.00–170.00 A, 0.01 A steps (phase-to-phase) 0.050–100.000 A, 0.010 A steps (residual ground)
1 A Nominal Phase Channels:	0.05–20.00 A, 0.01 A steps (phase & negative-sequence) 0.20–34.00 A, 0.01 A steps (phase-to-phase) 0.010–20.000 A, 0.002 A steps (residual ground)
5 A Nominal IN Channel:	0.250–100.000 A, 0.001 A steps (neutral ground)
1 A Nominal IN Channel:	0.050–20.000 A, 0.001 A steps (neutral ground)
0.2 A Nominal IN Channel:	0.005–2.500 A, 0.001 A steps (neutral ground)
0.05 A Nominal IN Channel:	0.005–1.500 A, 0.001 A steps (neutral ground)

Steady-State Pickup Accuracy

5 A Model:	±0.05 A, ±3%
1 A Model:	±0.01 A, ±3%
0.2 A IN Model:	±0.001 A, ±3%
0.05 A IN Model:	±0.001 A, ±5%
Transient Overreach:	±5% of pickup
Time Delay:	0.00–16,000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle, ±0.1%

Time-Overcurrent Elements (51)

Current Pickup (A secondary)

5 A Nominal Phase Channels:	0.25–16.00 A, 0.01 A steps (phase & negative-sequence) 0.10–16.00 A, 0.01 A steps (residual ground)
1 A Nominal Phase Channels:	0.05–3.20 A, 0.01 A steps (phase & negative-sequence) 0.02–3.20 A, 0.01 A steps (residual ground)
5 A Nominal IN Channel:	0.500–16.000 A, 0.005 A steps (neutral ground)
1 A Nominal IN Channel:	0.100–3.200 A, 0.001 A steps (neutral ground)
0.2 A Nominal IN Channel:	0.005–0.640 A, 0.001 A steps (neutral ground)
0.05 A Nominal IN Channel:	0.005–0.160 A, 0.001 A steps (neutral ground)

Pickup Accuracy

5 A Model:	±0.05 A, ±3%
1 A Model:	±0.01 A, ±3%
0.2 A IN Model:	±0.005 A, ±3%
0.05 A IN Model:	±0.001 A, ±5%
Time Dials:	±5% of pickup
US:	0.5–15.0, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Timing:	±1.50 cycles, ±4% between 2 and 30 multiples of pickup
0.05 A IN Model:	±3.50 cycles, ±4% between 2 and 30 multiples of pickup

Under- (27)/Overvoltage (59) Elements

Pickup Ranges:	0.00–300.00 V, 0.01 V steps (most elements)
Steady-State Pickup Accuracy:	±0.5 V, ±1% for 12.5–300.00 V
Transient Overreach:	±5%

5.3.X.X --> Under-/Overfrequency Elements (81)

Frequency:	40.1–65.00 Hz, 0.01 Hz steps
Time Delays:	2.00–16,000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle, ±0.1%
Steady-State *plus* Transient Overshoot:	±0.01 Hz
Undervoltage Frequency Element Block Range:	25.00–300.00 V

SELogic Control Equation Variable Timers

Pickup Ranges

0.00–999,999.00 cycles:	0.25-cycle steps (reclosing relay and some programmable timers)
0.00–16,000.00 cycles:	0.25-cycle steps (some programmable and other timers)
Pickup/Dropout Accuracy:	±0.25 cycle, ±0.1%

Substation Battery Voltage Monitor (Not in SEL-351A-1)

Pickup Ranges:	20–300 Vdc, 1 Vdc steps
Measuring Accuracy:	±2%, ±2 Vdc

Metering Accuracy

Accuracies specified at 20°C and at nominal system frequency unless otherwise noted

Temperature Coefficient:	[(0.0002%)/(°C)^2] • (__°C – 20°C)^2 (see example below)
Phase Angle Accuracy:	±0.5°

I_A, I_B, I_C, V_S
V_A, V_B, V_C (wye-connected voltages)
V_{AB}, V_{BC}, V_{CA} (delta connected voltages)

Voltages

V_A, V_B, V_C:	±0.2% (67.0–300 V, wye-connected)
V_{AB}, V_{BC}, V_{CA}:	±0.4% (67.0–300 V, delta-connected)
V_S:	±0.2% (67.0–300 V)
V_1, V_2, $3V_0$*:	±0.6% (67.0–300 V) * not available when delta-connected

Currents I_A, I_B, I_C

5 A Nominal:	±2 mA, ±0.1% (0.5–100.0 A)
1 A Nominal:	±0.5 mA, ±0.1% (0.1–20 A)

Currents I_N, I_1, $3I_0$, $3I_2$

5 A Nominal:	±0.05 A, ±3% (0.5–100.0 A)
1 A Nominal:	±0.01 A, ±3% (0.1–20.0 A)

Currents I_N

0.2 A IN Nominal:	±0.08 mA, ±0.1% (0.005–4.5 A)
0.05 A IN Nominal:	±1 mA, ±5% (0.01–1.5 A)

Appendix C

KOHLER. POWER SYSTEMS

TIB-102 1/07f

TECHNICAL INFORMATION BULLETIN

Alternator Data Sheet

Alternator Model: 7M4374

Kilowatt ratings at	1800 RPM		60 Hertz		6 LEADS	Standard Medium Voltage		
kW (kVA)	3 Phase		0.8 Power Factor			Dripproof or Open Enclosure		
	Class B	Class F				Class H		
Voltage*	80° C ① Continuous	90° C ① Lloyds	95° C ① ABS	105° C British Standard	105° C Continuous	130° C ① Standby	125° C British Standard	125° C Continuous	150° C ① Standby
4160	1525 (1906)	1680 (2100)	1680 (2100)	1860 (2325)	1875 (2344)	2050 (2563)	1860 (2325)	2050 (2563)	2050 (2563)

①Rise by resistance method, Mil-Std-705, Method 680.1b. *British Standard Rating per BS 5000*

Submittal Data: 4160 Volts*, 2050.4 kw, 2563 kVA, 0.8 P.F., 1800 RPM, 60 Hz, 3 Phase **STD. CONNECTION**

Mil-Std-705B Method	Description	Value
301.1b	Insulation Resistance	>1.5 Meg
302.1a	High Potential Test	
	Main Stator	2200 Volts
	Main Rotor	1500 Volts
	Exciter Stator	1500 Volts
	Exciter Rotor	1500 Volts
	PMG Stator	1500 Volts
401.1a	Stator Resistance, Line to Line	
	High Wye Connection	0.072 Ohms
	Rotor Resistance	1.196 Ohms
	Exciter Stator	22.1 Ohms
	Exciter Rotor	0.066 Ohms
	PMG Stator	2.1 Ohms
410.1a	No Load Exciter Field Amps at 2080/4160 Volts Line to Line	0.79 A DC
420.1a	Short Circuit Ratio	0.575
421.1a	Xd Synchronous Reactance	2.108 p.u.
		14.222 ohms
422.1a	X2 Negative Sequence React.	0.207 pu
		1.397 ohms
423.1a	X0 Zero Sequence Reactance	0.023 pu
		0.155 ohms
425.1a	X'd Transient Reactance	0.126 pu
		0.85 ohms
426.1a	X"d Subtransient Reactance	0.098 pu
		0.661 ohms
--	Xq Quadrature Synch. React.	Not Available
427.1a	T'd Transient Short Circuit Time Constant	0.178 sec.
428.1a	T"d Subtransient Short Circuit Time Constant	0.013 sec.
430.1a	T'do Transient Open Circuit Time Constant	2.55 sec.
432.1a	Ta Short Circuit Time Constant of Armature Winding	0.055 sec.

Mil-Std-705B Method	Description	Value
505.3b	Overspeed	2250 RPM
507.1c	Phase Sequence CCW-ODE	ABC
508.1c	Voltage Balance, L-L or L-N	0.20%
601.4a	L-L Harmonic Maximum - Total (Distortion Factor)	5.0%
601.4a	L-L Harmonic Maximum - Single	3.0%
601.1c	Deviation Factor	5.0%
---	TIF (1960 Weightings)	< 50
---	THF (IEC, BS & NEMA Weightings)	< 2 %
652.1a	Shaft Current	< 0.1 ma
---	Main Stator Capacitance to ground	0.014 mfd
	Additional Prototype Mil-Std Methods are Available on Request.	
--	Generator Frame	744
--	Type	MAGNAMAXDVR
--	Insulation	Class H
--	Coupling - Single Bearing	Flexible
--	Amortisseur Windings	Full
--	Excitation	Ext. Voltage Regulated, Brushless
--	Voltage Regulator	DVR2000
--	Voltage Regulation	0.25%
--	Cooling Air Volume	1130 CFM
--	Heat rejection rate	5655 Btu's/min
--	Full load current	356 amps
--	Minimum Input hp required	2881.8
	Efficiency at rated load :	95.4%
--	Full load torque	8405 Lb-ft

5.11.2.1

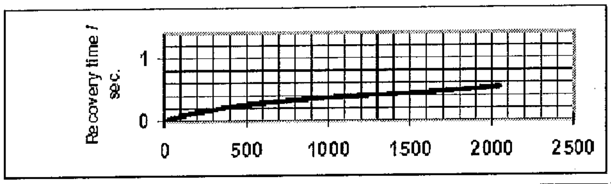
* Voltage refers to wye (star) connection, unless otherwise specified. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever.

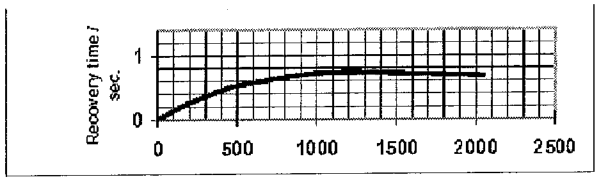
Appendix C

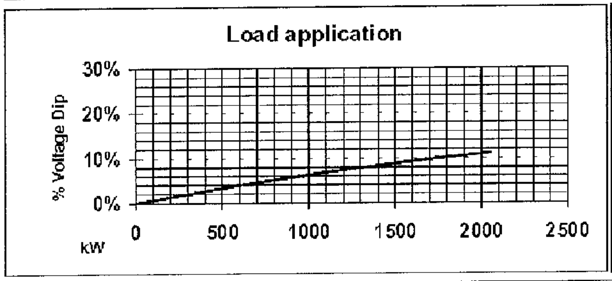
7M4374 60 Hz

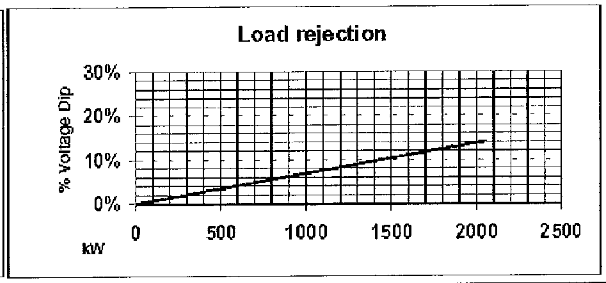
TYPICAL DYNAMIC CHARACTERISTICS

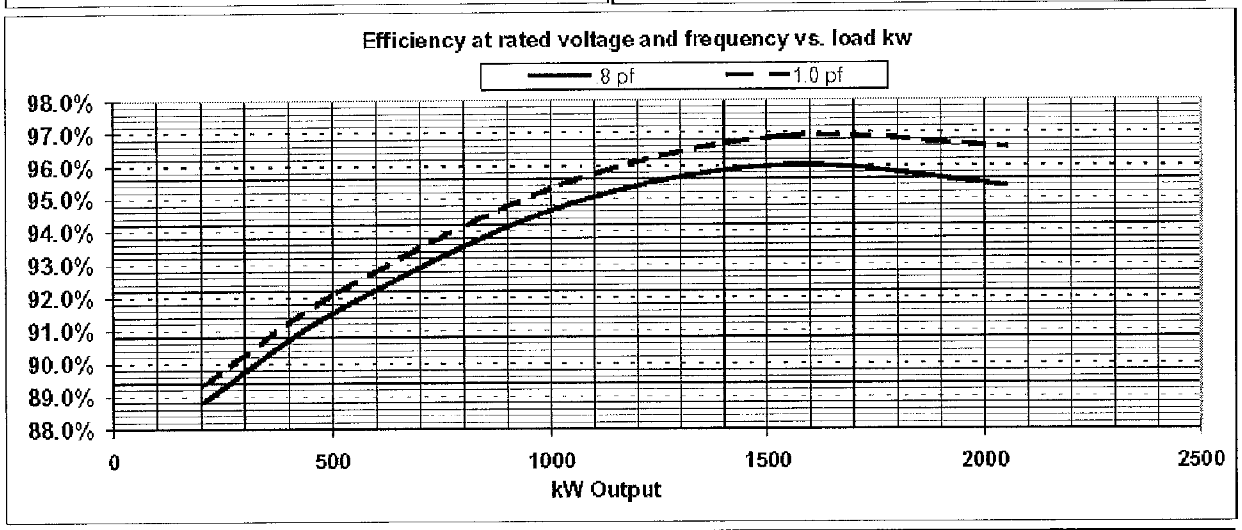
Alternator Model: 7M4374

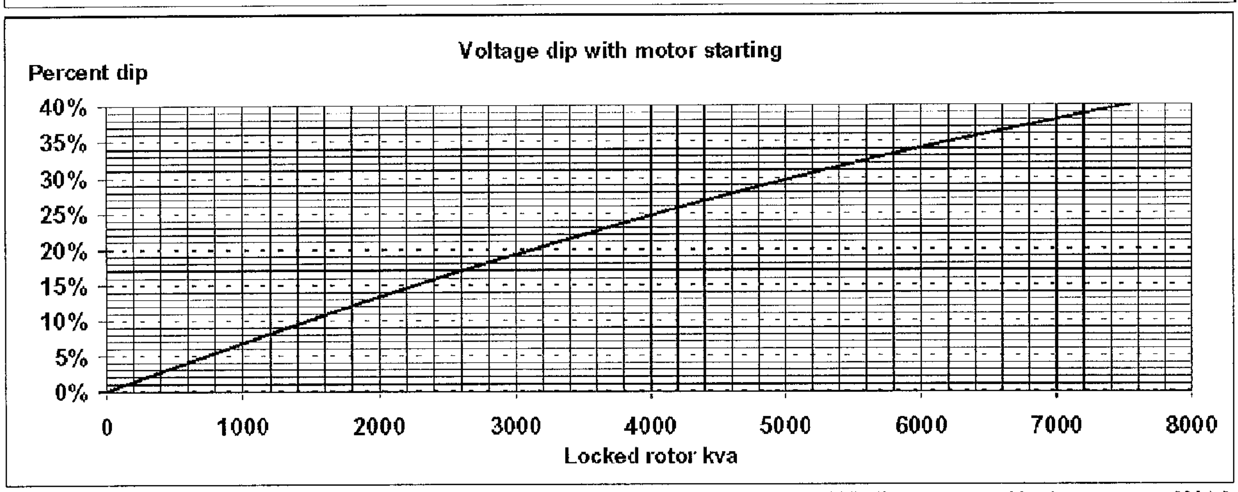












Data Rev. 11/01/95 Version: 2001.2

* Voltage refers to wye (star) connection, unless otherwise specified. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever.

Appendix C

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

Appendix 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)

5.0.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 (V_1 > 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:	Up 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 model: ±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

Appendix 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

Negative-Sequence Overcurrent Elements (46)

5.9.2

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 $\|I_2\|$ 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 C

5.4.X.X

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°

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

Appendix D

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	121.0	25
3	121	121.2	150
4	121	121.0	40
5	121	121.0	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	121.0	25
4	121	121.0	-45
5	121	121.0	30

C-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121.0	5
2	121	121.0	15
3	121	121.0	-5
4	121	121.0	20
5	121	121.0	15

3-Phase Over-Voltage Low Setting

Trial	Nominal (V)	Actual V	Deviation (mV)
1	121	121.1	70
2	121	121.0	25
3	121	121.1	90
4	121	121.0	40
5	121	121.0	35

Appendix D

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

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

Appendix D

5.2.1.2 Over-voltage Magnitude

A-Phase Over-Voltage High Setting			
Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156.0	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	156.0	20
2	156	156.0	30
3	156	156.0	10
4	156	156.0	40
5	156	156.0	45

C-Phase Over-Voltage High Setting			
Trial	Nominal (V)	Actual V	Deviation (mV)
1	156	156.1	65
2	156	156.0	20
3	156	156.0	40
4	156	156.0	10
5	156	156.0	30

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

Appendix D

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	-2.0
3	20	17	-3.0
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	3.020	3.025	4.6
2	3.020	3.025	5.2
3	3.020	3.025	4.7
4	3.020	3.025	4.6
5	3.020	3.025	5.4