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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023

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SECTION 26 05 63.00 98

COORDINATED POWER SYSTEM PROTECTION AND ARC FLASH ANALYSIS
07/20

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NOTE: This specification covers the requirements for the coordinated protection and arc flash analysis and labeling of electrical power systems.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Recommended changes to a NASAKSC Master Specification Section should be submitted as a Criteria Change Request (CCR) to the appropriate Technical Proponent (TP) through the SpecsIntact Help Desk.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the

Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text are automatically deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 242	(2001; Errata 2003) Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book
IEEE 399	(1997) Brown Book IEEE Recommended Practice for Power Systems Analysis
IEEE 1584	(2018; E 2019) Guide for Performing Arc-Flash Hazard Calculations
IEEE C2	(2023) National Electrical Safety Code

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA Z535.4	(2011; R 2017) Product Safety Signs and Labels

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023) National Electrical Code
NFPA 70E	(2024) Standard for Electrical Safety in the Workplace
UFC 3-310-04	(2013) Seismic Design for Buildings

1.2 PRE-INSTALLATION SUBMITTALS

No later than [90] [_____] days after Contract Award and prior to submission of electrical equipment and protective device product data, submit the following to the Contracting Officer for review and approval:

a. Fault Current Analysis

b. System Coordinator qualifications

c. Testing Agency qualifications[

d. Proposed Test Plan]

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project.

A “G” following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a “G”. Only delete an existing “G” if the submittal item is not complex and can be reviewed through the Contractor’s Quality Control system. Only add a “G” if the submittal is sufficiently important or complex in context of the project.

An "S" following a submittal item indicates that the submittal is required for the Sustainability Notebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Fault Current Analysis[; G][

] Proposed Test Plan[; G]

SD-03 Product Data

Software[; G]

Arc Flash Hazard Analysis[; G]

Protective Device Coordination Study[; G]

Equipment Evaluation Report[; G]

SD-04 Samples

Arc Flash Label Samples[; G]

SD-06 Test Reports

Field Testing[; G]

SD-07 Certificates

System Coordinator[; G]

Qualifications Of Testing Agency[; G]

Certificate of Conformance[; G]

1.4 ADMINISTRATIVE REQUIREMENTS

1.4.1 Review Submittals and Meetings

Submit the following to the Contracting Officer for review and approval:

a. Arc Flash Hazard Analysis Review Submittal

b. Protective Device Coordination Study Review Submittal

The Contractor and System Coordinator [agree to attend a review meeting at a location designated by the Contracting Officer and] provide review submittals as follows:

a. 90 percent submittal[and review meeting]: Study is complete except for disposition of Government comments.

b. 100 percent submittal: Incorporates approved Government comments. Setting sheets and test procedures from these documents are to be used to implement protective device settings.

[1.4.1.1 Proposed Test Plan

Submit a proposed test plan, consisting of complete field test procedure including tests to be performed, test equipment required, and tolerance limits, including complete testing and verification of the ground fault protection equipment, where used.

]1.4.2 Field Changes

If field changes are required due to discrepancies between the setting sheet documents and the available setting selections on the protective device, submit within [10] days after installation the following to the Contracting Officer for review and approval:

a. Fault Current and Arc Flash Analysis

b. Protective Device Coordination Study

1.5 QUALITY ASSURANCE

Ensure all work performed is in conformance with the following standards:

IEEE C2

IEEE 1584

NEMA Z535.4

NETA ATS

NFPA 70

NFPA 70E

1.5.1 System Coordinator

Provide documentation verifying that system coordination, recommended ratings and settings of protective devices, and design analysis are prepared (performed/reviewed/approved) by a registered professional electrical power engineer with a minimum of [three][_____] years of current experience in the coordination of electrical power systems.

Provide a list of references complete with points of contact, addresses and telephone numbers. The selection of the engineer is subject to the approval of the Contracting Officer.

1.5.2 Testing Agency

Ensure all final calibration, testing, adjustment, and placing into service of the protective devices must accomplished by an independent testing company with a minimum of [two] [_____] years of current product experience in protective devices. Submit name and qualifications of testing agency. Ensure the organization has a calibration program, and test instruments used must be calibrated in accordance with NETA ATS.

1.6 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING applies to this Section.

Coordinate requirements of this Section with all other Sections that specify electrical equipment and overcurrent protective devices.

1.7 PROJECT/SITE CONDITIONS

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NOTE: Unusual service conditions for altitude start above 1005 m (3300 feet) for most apparatus. Unusual ambient temperature ranges are minus 30 to 40 degrees C, but other ambients may apply. Frequency is generally 60 Hz, although 50 Hz may also be standard. Fungus control for electrical devices is required only in tropical areas.

Provide seismic requirements, if a Government designer is the Engineer of Record, and show on the drawings. Delete the inappropriate bracketed phrase. Pertinent portions of UFC 3-310-04 and Sections 13 48 00 SEISMIC PROTECTION FOR MECHANICAL EQUIPMENT, 13 48 00.00 10 SEISMIC PROTECTION FOR MECHANICAL EQUIPMENT, and 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT, properly edited, must be included in the contract documents.

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Provide devices and equipment suitable for the following seismic site conditions:

Provide Seismic details [conforming to UFC 3-310-04 and Sections 13 48 00 SEISMIC PROTECTION FOR MISCELLANEOUS EQUIPMENT, 23 05 48.19 [SEISMIC

]BRACING FOR HVAC, and 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT] [as indicated].

a. Altitude: [_____]

b. Ambient Temperature: [_____]

c. Frequency: [_____]

d. Fungus Control: [_____]

e. Hazardous Classification: [_____]

f. Humidity Control: [_____]

g. Ventilation: [_____]

h. Seismic Parameters: [_____]

i. Other: [_____]

PART 2 PRODUCTS

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NOTE: Select types to suit project conditions and delete all others. Delete all paragraphs not applicable.
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2.1 SYSTEM DESCRIPTION

The power system covered by this specification consists of: [_____].

Drawing: [_____]

Sheets: [_____]

The Government will provide the short circuit values for the following connection points on the electrical system:

[_____]

[_____]

[The Government will provide the existing protective device settings for the following devices on the electrical system:

[_____]

[_____]]

[The Government will provide the existing protective device time-current curves for the following devices on the electrical system:

Curve Set 1:

[_____]

[_____]

[_____]

Curve Set 2:

[_____]

[_____]

[_____]

]2.2 SOFTWARE

Provide software complying with IEEE 399. Ensure software program is capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program must report device settings and ratings of all overcurrent protective devices and demonstrate selective coordination by computer-generated, time-current coordination plots.

2.3 ARC FLASH LABELS

Provide weatherproof detailed arc flash warning labels for all electrical equipment as required by NFPA 70 and NFPA 70E, including, medium voltage switches, transformers, switchgear main breakers, switchgear bus-tie breaker, switchgear feeder breakers, switchgear cable compartments, switchboards, panel boards, motor control centers, enclosed breakers, safety switches automatic transfer switches, motor starters, control panels, and other equipment modified or installed by the project that is likely to require examination, adjustment, servicing, or maintenance while energized.

2.3.1 Label Format

Label format is to be in compliance with NFPA 70E and KSC label format. Coordinate with Contracting Officer to obtain copies of software data file label format from previously completed projects. If data file is not available for approved software, contractor will be responsible for creating label format based on example labels provided. Format includes different colors for different incident energy levels per NEMA Z535.4. Ensure labels contain the following information:

a. Arc Flash hazard boundary

b. Incident energy

c. Working Distance

d. Nominal System Voltage

e. Limited approach boundary distance

f. Restricted approach boundary distance

Submit arc flash label samples provided at the time of award.

2.3.2 Label Content

Ensure arc flash label content is based on the operational scenario, fault

location, and fault type (arcing or bolted) that results in the highest incident energy (worst-case).

Ensure labels for panelboards reflect incident energy calculated on the line side of the main circuit breaker. Switchboards, switchgear, and motor-control centers with full height barriers separating sections of the equipment will have two labels. One label on the incoming section reflecting the incident energy on the lines side of the main protective device and one label for the distribution sections reflecting incident energy on the load side of the main protective device. Ensure bus names shown on labels clearly indicate which is calculated on the line side of the main protective device.

2.4 COORDINATED POWER SYSTEM PROTECTION

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NOTE: The requirements for the studies in these paragraphs depend on the complexity and extent of the power system. Delete these requirements for: projects of limited scope; projects having protective devices which are not adjustable or for which coordination is not possible (standard molded case circuit breakers); projects involving simple extension of 600 volt level service to a building or facility from an existing transformer (750 kVA or less); or projects involving simple extension of 600 volt level service to a building or facility from a new transformer (750 kVA or less).

The designer is responsible for showing and specifying the requirements for fuses, circuit breakers, protective relays, or other protective devices associated with the project. The protective devices should be selected and specified to protect electrical power system conductors or equipment against sustained overloads, in-rush conditions, electrical faults, or other abnormal power system or equipment operating conditions, in accordance with UFC 3-520-01, IEEE 242, and IEEE Std 141.

The complexity and extent of coordinated power system protection depends on the type of buildings or facilities required, on the load demand of facilities, and on the quantity and types of facilities to be constructed. Facilities having a relatively-low power demand (e.g., 2500 kVA or less) generally require protection of: an incoming aerial distribution line or underground, medium-voltage feeder; low-voltage feeders to individual items of equipment, or to power distribution equipment, and branch circuits. More complex projects such as facilities with generating capacity, large motors, or larger load demands, will require more detailed and extensive coordinated power system protection.

Independent of the type or types of facilities or load demands, the coordinated power system protection will be based on: life safety, economics, simplicity, and the electrical power

availability dictated by the Using Agency or Service, or by the functional use of the facilities or utilities; requirement to provide maximum power service with a minimum of power interruptions; and the operating speed of protective devices required to minimize damage to electrical components or items of equipment and to prevent injury to personnel and nuisance tripping.

Unless otherwise approved, a dc power source will be shown and specified to ensure proper closing and tripping of protective devices which require a reliable power source during outage of the normal alternating-current power source.

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Prepare and submit analyses to demonstrate that the equipment selected and system constructed meet the contract requirements for ratings, coordination, and protection. Include a fault current analysis and arc flash hazard analysis with equipment evaluation report, and a protective device coordination study. Final analysis reports must be signed and sealed by the System Coordinator.

Prepare and submit short circuit studies, [load flow studies,] [motor starting analysis,] [coordination studies,] and arc-flash hazard analysis in accordance with IEEE 1584, NETA ATS, and as specified herein.

2.4.1 Scope of Analyses

Ensure all equipment that requires testing, adjustment, or servicing while energized is included in the analysis. Provide labels for all panelboards, switchboards, switchgear, motor-control centers, variable frequency drives, and disconnect switches rated 100A and greater. Single phase equipment, disconnect switches rated less than 100A, junction boxes, pull boxes, and control panels may be excluded from the analysis.

Ensure the fault current and arc flash analysis, and protective device coordination study begin at:

[The source bus and extend down to system buses where fault availability is 10,000 amperes (symmetrical) for building/facility 600 volt level distribution buses.

][The source bus and extended through the secondary side of transformers for medium voltage distribution feeders.

][The source bus and extend through [outgoing breakers] [outgoing medium voltage feeders, down to the individual protective devices for medium voltage radial taps]

][Outgoing medium voltage feeders, through the secondary side of transformers

][[As indicated] for main electric supply substations.

][The nearest upstream device in the existing source system and extend through the downstream devices at the load end.

]2.4.2 Determination of Facts

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NOTE: Require the Contractor to obtain an available fault capacity at the power source or provide a fault capacity on which to base the analysis. Delete the unused option.
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Perform field inspections to determine and document the time-current characteristics, features, and nameplate data for each existing protective device. [Coordinate with the [commercial power company] [_____] for fault current availability at the site.] [Utilize the fault current availability indicated as a basis for fault current studies.]

2.4.3 Single Line Diagram

Prepare a single line diagram to show the electrical system buses, devices, transformation points, and all sources of fault current (including generator and motor contributions). A fault-impedance diagram or a computer analysis diagram may be provided. Ensure each bus, device or transformation point has a unique identifier. If a fault-impedance diagram is provided, show impedance data. Show the location of switches, breakers, and circuit interrupting devices on the diagram together with available fault data, and the device interrupting rating.

2.4.4 Fault Current Analysis

2.4.4.1 Method

Perform the fault current analysis in accordance with methods described in IEEE 242, and IEEE 399. Single line drawings based on existing hardware will be provided to the Contractor for reference. Utilize specialized computer aided engineering software designed for fault current analysis, including the following capabilities:

a. Single-ended substation source operation

b. Double-ended substation source operation

c. Generator source operation

Perform analysis and provide separate study report generated for each operational scenario.

2.4.4.2 Data

Utilize actual hardware data in fault calculations. Ensure bus characteristics and transformer impedance are those proposed. Document all data in the report.

2.4.4.3 Fault Current Availability

Provide balanced three-phase fault, bolted line-to-line fault, and line-to-ground fault current values at each voltage transformation point and at each power distribution bus. Show the maximum and minimum values of fault available at each location in tabular form on the diagram or in the report.

2.4.5 Coordination Study

Ensure the study demonstrates that the maximum possible degree of selectivity has been obtained between devices specified, consistent with protection of equipment and conductors from damage from overloads and fault conditions. Include a description of the coordination of the protective devices in this project. Provide a written narrative describing:

a. Which devices may operate in the event of a fault at each bus; the logic used to arrive at device ratings and settings;

b. Situations where system coordination is not achievable due to device limitations (an analysis of any device curves which overlap);

c. Coordination between upstream and downstream devices; and relay settings.

d. Provide recommendations to improve or enhance system reliability by reducing the incident energy level, and detail where such changes would involve additions or modifications to the contract and cost damages (addition or reduction).

Provide composite coordination plots on log-log graph paper.

a. Provide separate plots for phase and ground faults.

b. Include applicable cable and transformer damage curves on phase fault plots.

c. Limit the number of protective device curves on any plot to [5] [_____].

2.4.6 Study report

Include the following in the report:

a. A cover sheet and table of contents. Provide separate sections with all applicable content, for all operating scenarios.

b. A narrative describing:

(1) The analyses performed;

(2) The basis and methods used;

(3) The desired method of coordinated protection of the power system.

c. Descriptive and technical data for existing devices and new protective devices proposed, including manufacturers published data, nameplate data, time-current curves, and definition of the fixed or adjustable features of the existing or new protective devices.

d. Document [utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristic curves, current transformer ratios, and relay device numbers and settings;] [and] [existing power system data including time-current characteristic curves and protective device ratings and settings].

e. Provide time-current characteristics curves for each bus in the system, as required to ensure coordinated power system protection between protective devices or equipment, including recommended ratings and settings of all protective devices in tabulated form.

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NOTE: Requirement to use SKM, ETAP, or other specific software packages will generally require approval of a sole-source justification. If no such justification has not been approved then do not select a particular software requirement.
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f. Provide all calculations performed for the analyses. Include all information input to (define) nodes such as cable data, conduit type, circuit length, transformer impedance, bus impedance, generator impedances, etc. For all nodes include phase fault short circuit levels and X/R ratios, ground fault short circuit levels and X/R ratios, load flow levels, arc flash energy (for both bolted and arcing short circuit levels), and motor starting studying results. Indicate which study options have been chosen which the software utilizes to generate the Short Circuit Analysis and Arc Flash Hazard Analysis results; use preferred method below when available. Options included are, but not limited to the following:

(1) Standard used for arc-flash calculations: (IEEE 1584 - preferred method).

(2) 240 Volt Exceptions (report Cat 0 if XFMR less than 125kVA - preferred method).

(3) Maximum arcing time: (2 sec - preferred - fully dependent on task performed). For certain tasks, such as working in manholes, elevated work areas, or underneath equipment, it may not be possible for trained personnel to distance themselves from the Arc Flash within 2 seconds.

(4) Motor fault contributions: (5 cycles preferred - motors or motor groups totaling 50 hp or greater are to be evaluated).

(5) Levels Mis-coordination checked (5 levels-preferred).

(6) Mis-coordination Ratio: (80 percent - preferred - ensure Cleared Fault Threshold matches Mis-coordination Ratio).

(7) Flash Boundary Calculation Adjustments above 1kV, Trip Time less than =0.1s: (1.5 cal/square meter - preferred).

(8) Properly categorize all equipment types in Arc Flash Evaluation: (Ensure switchgear, panel boards have proper gap distance).

(9) Utility information from latest [_____] Area Load Flow and Fault Study ([_____] [local utility company only] -preferred).

(10) Short Circuit Study Utilized: (Comprehensive-preferred).

(11) Fault types analyzed: (Three Phase, Single Line to Ground, Line to Line, Line to Line to Ground, All -preferred).

g. Single line diagram(s)

h. Protective device setting sheets, as separate pages, suitable for use by installing technicians, separate from other report analysis and data. Include recommended changes to existing protective device settings and settings for all new protective devices. Provide all information to field install the settings, including settings or features not used or turned off.

i. Tabulated Arc Flash data for all equipment requiring an arc flash warning label and all modified equipment also requiring an arc flash label.

j. Equipment Evaluation Report (EER) showing the AIC/SCCR ratings for all equipment evaluated and the required rating for the application where the equipment is installed. Ensure the EER identifies underrated and marginally rated equipment. Underrated equipment is defined as equipment with actual AIC/SCCR ratings that do not meet the required AIC/SCCR rating for the application/installation. Marginally rated equipment is defined as equipment within 90 percent to 100 percent of the required rated AIC/SCCR for the application/installation.

PART 3 EXECUTION

3.1 INSTALLATION

Install and test protective devices settings in accordance with the manufacturer's published instructions and in accordance with the protective device coordination study protective device setting sheets and test plan.

Affix detailed arc flash warning labels to all electrical equipment as required by NFPA 70 and NFPA 70E.

3.2 FIELD TESTING

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NOTE: Select types to suit project conditions and delete all others. Delete all paragraphs not applicable.
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3.2.1 General

Section 26 08 00 APPARATUS INSPECTION AND TESTING, applies to this section, with the additions and modifications specified herein. Submit Performance Test Reports ishowing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria, upon completion and testing of the installed system. Indicate in each test report the final position of settings and controls. Submit Certificate of Conformance to the Contracting Officer, certifying that all devices or equipment meet the requirements of the contract documents.

3.2.2 Safety

Provide and use safety devices such as arc flash personal protective equipment, electrically insulating rubber gloves, protective barriers, and danger signs to protect and warn personnel in the test vicinity. Replace

any devices or equipment which are damaged due to improper test procedures or handling.

3.2.3 Molded-Case Circuit Breakers

Visually inspect circuit breakers. Verify current ratings and adjustable settings incorporated in accordance with the coordination study.

3.2.4 Power Circuit Breakers

3.2.4.1 General

Visually inspect the circuit breaker and implement settings in accordance with the coordination study.

3.2.4.2 Current Injection Tests

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NOTE: These tests below are typical for NETA acceptance testing as specified in Section 26 08 00 APPARATUS INSPECTION AND TESTING or other protective device sections and should be coordinated between sections accordingly.
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Test with approved settings installed in accordance with NETA ATS and the Test Plan; document results in the field test reports.

a. Determine long time pick-up value and delay by primary current injection.

b. Determine short time pick-up value and delay by primary current injection.

c. Determine instantaneous pick-up value by primary current injection.

d. Determine ground-fault pick-up value and delay by primary current injection.

e. Test trip unit functions by secondary current injection or in accordance with the manufacturer's requirements.

3.2.5 Protective Relays

3.2.5.1 General

Visually inspect protective relays. Implement relay settings in accordance with the coordination study.

3.2.5.2 Current Injection Tests

Test with approved settings installed in accordance with NETA ATS and the Test Plan; document results in the field test reports.

a. Determine long time pick-up value and delay by secondary current injection.

b. Determine short time pick-up value and delay by secondary current injection.

c. Determine instantaneous pick-up value by secondary current injection.

d. Determine ground fault pick-up value and delay by secondary current injection.

-- End of Section --