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USACE / NAVFAC / AFCEC **UFGS 26 37 13 (February 2024)**

Preparing Activity: USACE **New**

MICROGRID CONTROL SYSTEM

References are in agreement with UMRL dated July 2025
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SECTION 26 37 13

MICROGRID CONTROL SYSTEM
02/24

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NOTE: This guide specification covers the requirements of a Microgrid Control System (MCS) in accordance with UFC 3-550-04 Installation Microgrid Design and IEEE 2030.7. The MCS may consist of a central controller or distributed control logic executed among multiple discrete devices.

This specification covers only the microgrid control system, and does not include specification for connected Distributed Energy Resources, controlled loads and devices, or external communication systems. Coordination of the requirements selected or edited within this guide specification is required with connected, controlled, or integrated components and equipment defined elsewhere within the UFGS. Refer to the further designer notes regarding these sections in the REFERENCES portion of this guide specification.

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 item(s) or insert appropriate information.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR). CCRs for this specification can be submitted through the Whole Building Design Guide page for this section:
https://www.wbdg.org/dod/ufgs/ufgs-26-37-13

****

PART 1 GENERAL

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NOTE: This guide specification makes use of the SpecsIntact tailoring options for service-specific requirements for the Air Force, Army, and Navy as well as a 'Service Generic' tailoring option for use on other projects. In order for this specification to be properly tailored one (and only one) of the services tailoring options (Air Force, Army, Navy, Service Generic) must be selected.
****

1.1 SUMMARY

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NOTE: Ensure the MCS defined by this specification complies with UFC 3-550-04. Critical design elements that must be provided by the Designer of Record to inform and supplement this specification include but are not limited to:
*** Load Analysis; using highest resolution data available**
*** In-rush and startup load analysis**
*** Grid modeling**
*** Short Circuit and Arc Flash Study for new and modified components**
*** Grounding system analysis (with consideration given to ground path in all modes of operation)**
*** Protection analysis, including verification of island mode short circuit current in relation to minimum current required to activate protective devices.**
*** List of devices and device IDs**
*** Communication pathways and conduits; often microgrid controllers require communication with physically distant equipment.**
****

The Microgrid Control System defined herein monitors and controls the operation of the microgrid equipment. This specification refers only to that control system and does not include specification of the connected equipment which comprises the microgrid such as Distributed Energy Resources (DERs), controlled loads, distribution or utilization circuits, low, medium, or high-voltage protective devices, or other similar components specified elsewhere.

1.1.1 System Requirements

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NOTE: Select the appropriate text in the type specific communication system requirements to indicate whether or not the IP network will be Government furnished. If the IP network is *not* Government furnished be sure to include complete requirements for the IP network in the contract package. This specification does not provide sufficient requirements for the procurement of an IP network.

Use "[an IP network as specified in [_____] and]" only if the contractor is expected to install an IP

network. In this case provide the information on the specification for the IP network in the "[_____]" provided.

For Army, coordinate with the installation (DPW and NEC) but the default selection will be "[the Government furnished IP network]"
****

Provide an electrical Microgrid Control System (MCS) as specified and indicated, and in accordance with the following characteristics:

1.1.1.1 General MCS Requirements

****
NOTE: Select the appropriate bracketed options in order to define the larger functions of the MCS in relation to the microgrid. The selected options should be coordinated with the design drawings accompanying this specification.
****

a. Scope of Control: The MCS controls the microgrid system. The microgrid is defined as [a bounded electrical system with a single point of interconnection][a bounded electrical system with multiple points of interconnection] with an external grid. The system includes DERs, distribution devices, dispatchable and non-dispatchable loads, controls, and communication systems.

b. Fault Management: MCS supervisory monitoring and control functions include but are not limited to automated fault detection, microgrid isolation from the external electrical grid, and internal system reconfiguration capabilities to maintain critical load supply.

c. Component Standards: Provide components and technology which are commercial, warrantied, and intended for permanent installation. Materials and equipment must be standard unmodified products of a manufacturer regularly engaged in the manufacturing of such products. Units of the same type of equipment must be products of a single manufacturer. Items of the same type and purpose must be identical and supplied by the same manufacturer, unless replaced by a new version approved by the Government.

d. Island Mode Operation: Ensure the Microgrid Control system operates the microgrid in island mode, paralleling either one or more than one disparate source of generation, with at least one grid-forming DER [with][without] droop control.

e. Black Start Capability: Equip the MCS to manage the microgrid black start procedure. Initiate the startup of [one][more than one] firm-generation grid-forming DER asset(s) after an unplanned external grid outage.

f. Load Management: Incorporate functionality within the MCS to dispatch DER and direct load shedding, ensuring the islanded system generation meets the critical load within the system boundary.

g. Operational Modes: Equip the MCS with functionality to direct transitions between operational modes, including but not limited to black start in island mode, automatic transition from grid-connected to islanded mode, resynchronization and reconnection to grid-connected mode from islanded mode, and system balancing. Manage energy to optimize both real and reactive power generation and consumption for microgrid-connected load resilience,[operational efficiency,][economic benefits,][optimal external grid resilience,][decarbonization] purposes[, and][support of the grid,][participation in the energy market,][and utility system demand response] through DER and load dispatch.

h. Critical Load Uptime: For critical loads supplied by the microgrid, equip the MCS with functionality to support a minimum uptime of [99.9 percent][99.99 percent][99.999 percent][99.9999 percent] as defined and required by [UFC 3-520-02][Office of the Under Secretary of Defense Memo "Metrics and Standards for Energy Resilience at Military Installations"].

i. System Interface: Ensure the MCS is arranged and interconnected such that it serves as the single point of interface with all microgrid DERs, DER Management System (DERMS), or UMCS. If necessary, allow the microgrid control system to perform UMCS functions required to dispatch microgrid resources.

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NOTE: Only allow for remote breaker operation where the facility has both qualified personnel regularly staffed and written standard operating procedure for remote operation. Confirm with Government before including.

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j. Monitoring and Control: Equip the MCS with supervisory monitoring and control functions, including but not limited to: [Point of Common Coupling (PCC) monitoring and control,][frequency control,][load shedding,][anti-islanding,][low- or high- voltage or frequency ride-through,][voltage (reactive power) control,][remote breaker control and monitoring in accordance with facility SOP,][synchronization,]and power quality monitoring.

k. Grid Interface: Coordinate the microgrid and microgrid system controller to present to the larger grid as [a single entity][____] with [a single point][multiple points] of electrical interconnection and a single control and communication interface between the microgrid and external grid. Ensure all MCS control and reporting functions appear as a single entity to all external devices. Execute functions defined herein from that single point of interconnection.

l. Human Machine Interface: System includes human-machine interface with graphical interface into the MCS.[Incorporate a primary interface position where all described microgrid control and HMI functions are accessible.] The HMI must allow for graphical navigation between systems, graphical representations of systems and interconnection, access to real-time data for systems, ability to override points in a system, and access to all supervisory monitoring and control functions.

m. Control Workstation: [The Government will provide the] [Provide a standard desktop computer or a laptop meeting the following minimum requirements for the] Computer Workstation Hardware (workstation) in accordance with this specification.

n. Software Licenses: Provide all necessary software documentation, configuration information, configuration tools, programs, drivers, and other software. Ensure they are licensed to and remain with the Government so that the Government or their agents can repair, replace, upgrade, and expand the system without subsequent or future dependence on the Contractor. Software licenses must [not require periodic fees and be valid in perpetuity][be valid for a period of not less than [three][five][_____] years].

o. Documentation: Supply sufficient documentation and data, including rights to documentation and data, enabling the Government or their agents to execute work to repair, replace, upgrade, expand, and cyber-secure the system without subsequent or future dependence on the Contractor.

1.1.1.2 Symbols, Definitions, and Abbreviations

Use symbols, definitions, and engineering unit abbreviations indicated in the contract drawings for displays, submittals and reports. For symbols, definitions and abbreviations not in the contract drawings use terms conforming at a minimum to IEEE Standards Dictionary as applicable.

1.1.1.3 System Units and Accuracy

Use metric (SI) units for all electrical values and[metric (SI)][English (inch pounds)] for all other values for displays, print-outs and calculations. Ensure calculations have an accuracy of at least three significant figures and present values on displays and printouts to at least three significant figures.

1.2 RELATED SECTIONS

****

NOTE: A number of these referenced sections will require updating to coordinate with the contents of the microgrid controller as specified. Ensure each section also includes a reference to this section where the other equipment will interface with the microgrid control system.

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Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS

1.2.1 Cybersecurity Requirements

****

NOTE: If Section 25 05 11 has been renumbered and/or renamed use the blank brackets to indicate the appropriate section, otherwise keep the reference to Section 25 05 11.

Designers refer to UFC 4-010-06 for cybersecurity design and coordination requirements with Government. Potential interconnections to other control systems or infrastructure owned and operated by activities outside of the DoD are coordinated and approved by the Government prior to procurement and installation by the contractor.

Do not edit these requirements (beyond selection of bracketed text). These default requirements should only be used in lieu of technology-specific requirements in the preceding paragraphs. If these default requirements are inappropriate, ensure that the preceding paragraphs provide appropriate technology-specific requirements.

****

Cybersecurity requirements related to this Section are specified in [Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS][a separate cybersecurity specification derived from Section 25 05 11][_____].

For NAVY Projects include Section 25 08 11.00 20 RISK MANAGEMENT FRAMEWORK FOR FACILITY-RELATED CONTROL SYSTEMS in addition to requirements found in Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS. Section 25 08 11.00 20 covers the Navy requirements to support the Risk Management Framework (RMF) Authority to Operate (ATO) Process for Facility-Related Control Systems.

1.2.2 Distributed Energy Resources

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NOTE: Coordinate the operational modes of the microgrid with relevant air quality standards in relation to carbon emitting generation assets. Where the microgrid will allow parallel or grid-supporting operation of these assets, ensure the generator's specification, typically Section 26 32 15 ENGINE-GENERATOR SET STATIONARY 15-2500 KW, WITH AUXILIARIES is coordinated with the applicable requirements.

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NOTE: Where ESS utilize lithium-ion battery technology, additional fire protection and alarm requirements must be provided per UFC 3-600-01. Refer also to UFGS for the specified equipment, whether provided under this project or existing.

****

[a. Evaluate reciprocating gensets in the microgrid for their operational mode as [parallel to the utility grid][, and][prime/continuous][standby/emergency]. Where carbon-emitting gensets operate in parallel to the utility, ensure compliance with [EPA Tier 1][EPA Tier 2][EPA Tier 3][EPA Tier 4] emission guidelines. Determine if the utility contract [permits][permits momentarily][prohibits] parallel operation. [Refer to Section 26 05 73 POWER SYSTEM STUDIES.]]

[b. Ensure turbine gensets, when serving as prime power sources, adhere to EPA tier emission guidelines if operating in parallel with the utility grid. Confirm the utility contract or interconnection agreement [permits][permits momentarily][prohibits] parallel operation.]

[c. Ensure the microgrid control system interfaces with, providing control and communication as outlined throughout this specification for [existing solar photovoltaic arrays][solar photovoltaic arrays provided under this contract] using compatible [string][central][micro-]inverter technology. If necessary, ensure inverters can control real and reactive power and comply with grid interconnection standards, including IEEE 1547[and UL 1741].[Refer to [Section 48 14 00 SOLAR PHOTOVOLTAIC SYSTEMS][______].]]

[d. Integrate Energy storage systems (ESS) into the microgrid control system for purposes such as load leveling, peak shaving, and backup power. Ensure the ESS can control both charge and discharge, with real and reactive power capabilities. Specify the storage capacity based on the microgrid's operational objectives and ROI considerations. [Refer to Section [_____]].]

[e. Incorporate wind generation systems into the microgrid control system. Choose electrical connection technology types from [Type 3 (Doubly Fed Induction Generator)][Type 4 (Full Converter)]. Ensure the wind generation system controls real and reactive power and adheres to grid interconnection standards. [Refer to Section 48 15 00 WIND GENERATOR SYSTEM]]

1.3 REFERENCES

****

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 (Reference ID) 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 will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

ASTM INTERNATIONAL (ASTM)

ASTM E772 (2015; R 2021) Standard Terminology of Solar Energy Conversion

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1547 (2018) Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE 1613 (2023) Environmental and Testing Requirements for Devices with Communications Functions used with

	Electric Power Apparatus
IEEE 2030.7	(2017) The Specification of Microgrid Controllers
IEEE 2030.8	(2008) The Testing of Microgrid Controllers
IEEE C37.90.1	(2023; ERTA) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.2	(2004; R 2010) Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
IEEE C62.41.1	(2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE C62.41.2	(2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE Stds Dictionary	(2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60068-2-1	(2007) Environmental testing - Part 2-1: Tests - Test A: Cold
IEC 60068-2-2	(2007) Environmental testing - Part 2-2: Tests - Test B: Dry heat
IEC 60068-2-30	(2005; ED 3.0) Environmental Testing - Part 2-30: Tests - Test Db: Damp Heat, Cyclic (12 H + 12 H Cycle)
IEC 60068-2-78	(2012) Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state
IEC 60255-1	(2022) Measuring relays and protection equipment - Part 1: Common Requirements
IEC 60255-21-1	(1988) Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section One: Vibration tests
IEC 60255-21-2	(1988) Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section Two: Shock and bump tests
IEC 60255-21-3	(1993; ED 1.0) Electrical Relays - Part 21: Vibration, Shock, Bump And Seismic Tests On Measuring Relays And Protection

	Equipment - Section 3: Seismic Tests
IEC 60255-26	(2023) Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements
IEC 61000-4-4	(2012) Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
IEC 61000-4-8	(2009) Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test
IEC 61131-3	(2025) Programmable Controllers - Part 3: Programming Languages
IEC 61850	(2021) Communication networks and systems for power utility automation

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISA 5.2	(1976; R1992) Binary Logic Diagrams for Process Operations
ISA 18.2	(2016) Management of Alarm Systems for the Process Industries
ISA 101.01	(2015) Human Machine Interfaces for Process Automation Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 1 2024; TIA 24-1; TIA 25-2) National Electrical Code
NFPA 262	(2023) Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces

U.S. DEPARTMENT OF DEFENSE (DOD)

DODI 8500.01	(2014) Cybersecurity
DODI 8510.01	(2022) Risk Management Framework for DOD Systems
MIL-STD-3071	(2023) Tactical Microgrid Communications and Control
UFC 1-300-02	(2014; with Change 3, 2021) Unified Facilities Guide Specifications (UFGS)

Format Standard

UFC 3-520-02	(2023; with Change 1, 2025) Facility Energy System Resilience And Reliability

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC EMC	(2002) FCC Electromagnetic Compliance Requirements
FCC Part 15	Radio Frequency Devices (47 CFR 15)

UL SOLUTIONS (UL)

UL 1741	(2010; Reprint Jan 2015) UL Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
UL 60950	(2000; Reprint Oct 2007) Safety of Information Technology Equipment

1.4 ACRONYMS

Acronym	Term
ARC	Communication Architecture
ATS	Automatic Transfer Switch
DER	Distributed Energy Resource
DERMS	DER Management System
DFD	Data Flow Diagram
DMS	Distribution Management System
FAT	Factory Acceptance Test
HIL	Hardware in the Loop
HMI	Human Machine Interface
IBR	Inverter-Based Resource
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISE	Interconnection System Equipment
IT	Information Technology
LAN	Local Area Network

Acronym	Term
MCS	Microgrid Control System
MEMS	Micro-Electro-Mechanical Systems
NEC	National Electric Code (NFPA 70)
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
OT	Operational Technology
PCC	Point of Common Coupling
POI	Point of Interface
PV	Photovoltaic
RPM	Revolutions Per Minute
ROI	Return on Investment
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
SER	Sequential Events Recorder
SOE	Sequence of Events
SOP	Standard Operating Procedure
UL	Underwriters Laboratory
UPS	Uninterruptible Power Suppl

1.5 DEFINITIONS

1.5.1 IEEE Stds Dictionary

For terms not explicitly defined in this section, refer to the IEEE Stds Dictionary.

1.5.2 ASTM E772

For terms related to solar energy, refer to ASTM E772 for definitions and standard terminology.

1.5.3 Anti-Islanding

A safety mechanism that detects when a microgrid has been separated from the main grid and ensures that the microgrid does not continue to feed power back into the disconnected grid.

1.5.4 Automatic Transfer Switch (ATS)

A switch that automatically transfers a power supply from its primary source to a backup source when it senses a failure or outage in the primary source.

1.5.5 Base Load Power DER

A DER that provides a constant output to meet minimum load requirements.

1.5.6 Black Start

The process of restoring a disabled or shut down microgrid to operation without relying on the external electric power transmission network.

1.5.7 Distributed Energy Resource Management System (DERMS)

A control system that allows for the centralized control of DERs within the microgrid, often integrated into the microgrid control system.

1.5.8 Firm Electrical Output DER

A DER capable of providing a guaranteed level of output under specified conditions.

1.5.9 Grid Following

A mode of operation where the DER adjusts its output based on grid conditions but cannot independently maintain grid voltage and frequency.

1.5.10 Grid Forming

A mode of operation where the DER can independently control voltage and frequency within a microgrid, effectively forming a grid.

1.5.11 Grid Forming DER

A DER capable of operating in a grid-forming mode, independently controlling voltage and frequency within a microgrid.

1.5.12 Human-Machine Interface (HMI)

The user interface that connects an operator to the controller in an industrial system, often a part of the microgrid control system.

1.5.13 Inverter-Based DER

A DER that uses an inverter to convert its output to alternating current (AC) for grid interconnection.

1.5.14 Islanding

Condition in which a microgrid operates independently and electrically isolated from the external grid.

1.5.15   Load Following DER

A DER that adjusts its output in real-time to match fluctuations in load demand.

1.5.16   Microgrid

A localized energy system consisting of DERs and loads capable of operating in parallel with, or independently from, the main power grid.

1.5.17   Point of Common Coupling (PCC)

The demarcation point between the owned electrical system of the microgrid and the utility distribution system.

1.5.18   Power Quality Correcting DER

A DER that provides ancillary services to improve power quality, such as voltage and frequency regulation.

1.6   ADMINISTRATIVE REQUIREMENTS

****

NOTE: The subparts below are specific to each installation location and project. As the designer, provide additional information required to understand the context of the project being specified.

****

The contractor is responsible for the complete installation, testing, and commissioning of the Microgrid Control System (MCS) in accordance with the project's Division 01 Specification. The contractor must also coordinate with other trades and disciplines to ensure seamless integration of the MCS with other systems, including but not limited to DERs, UMCS, and existing utility infrastructure.

1.6.1   Pre-Installation Meeting

In accordance with UFC 1-300-02, a pre-installation meeting is required be held to discuss plans, procedures, responsibilities, and the impact on existing facilities. The meeting must include, but is not limited to, the following:

[1.6.1.1   Coordination with Other Trades

Discussion of coordination requirements with other trades to ensure seamless integration of the MCS into the larger project infrastructure.

]1.6.1.2   Phasing Plan

Prepare and submit a Phasing Plan that includes listing for duration and estimated start date for any and all outages of existing assets impacted by the installation of the MCS. Include outages or simulated outages related to testing as in accordance with Part 3 EXECUTION. Include in the submitted equipment phasing plan an Integration Plan for MCS with existing or planned assets, a detailed Phasing Plan outlining outages and coordination, and Risk Mitigation Strategies.

[1.6.1.3 Related Project Coordination

Discussion of interface with concurrent, prior, or subsequent projects which may interface with the microgrid or microgrid control system.

]1.7 SUBMITTALS

****

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. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

****

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. Submittals not having a "G" or "S" classification are 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

Utility Interconnection Agreement; G, [_____]

Phasing Plan; G, [_____]

SD-02 Shop Drawings

Contractor Design Drawings; G, [_____]

Draft As-Built Drawings; G, [_____]

Microgrid Control System HMI Graphical Mockup; G, [_____]

SD-03 Product Data

Product Data Sheets; G, [_____]

Computer Hardware Specifications; G, [_____]

Computer Software Specifications; G, [_____]

SD-04 Samples

Enclosure Keys; G, [_____]

SD-05 Design Data

Power System Studies; G, [_____]

Microgrid System Architecture Diagram; G, [_____]

SD-06 Test Reports

Comprehensive Execution Plan; G, [_____]

Site Assessment Survey; G, [_____]

Factory Test Procedures; G, [_____]

Factory Test Report; G, [_____]

PVT Testing Procedures; G, [_____]

PVT Phase I Testing Report; G, [_____]

PVT Phase II Testing Report; G, [_____]

PVT Phase III Testing Report; G, [_____]

Startup Testing Plan; G, [_____]

Startup Testing Report; G, [_____]

Factory Acceptance Test Reports; G, [_____]

Pre-construction QC checklist; G, [_____]

Post-construction QC checklist; G, [_____]

SD-07 Certificates

Regulatory Compliance Documentation; G, [_____]

ISO 9001 Compliance Certificate; G, [_____]

Installer Qualifications; G, [_____]

Utility Interconnect Contract

SD-10 Operation and Maintenance Data

Emergency Response Plan; G, [_____]

Training Documentation; G, [_____]

Operation And Maintenance Instructions; G, [_____]

SD-11 Closeout Submittals

Enclosure Keys; G, [_____]

Closeout QC Checklist; G, [_____]

Microgrid System Model; G, [_____]

1.8 DATA PACKAGE AND SUBMITTALS REQUIREMENTS

****

NOTE: Coordinate the review of all submittals with the project site. The site may have a System Integrator or other individual/office that should review all submittals before acceptance of the system.

The acquisition of all technical data, data bases and computer software items that are identified herein will be accomplished strictly in accordance with the Federal Acquisition Regulation (FAR) and the Defense Acquisition Regulation Supplement (DFARS). Those regulations as well as the Services implementations thereof should also be consulted to ensure that a delivery of critical items of technical data is not inadvertently lost. Specifically, DFARS 252.227-7013 Rights in Technical Data - Noncommercial Items as well as any requisite software licensing agreements will be made a part of the CONTRACT CLAUSES or SPECIAL CONTRACT REQUIREMENTS.

In addition, the appropriate DD Form 1423 Contract Data Requirements List, will be filled out for each distinct deliverable data item and made a part of the contract. Where necessary, a DD Form 1664, Data Item Description, will be used to explain and more fully identify the data items listed on the DD Form 1423. It is to be noted that all of these clauses and forms are required to ensure the delivery of the data in question and that such data is obtained with the requisite rights to use by the Government.

Include with the request for proposals a completed DD Form 1423, Contract Data Requirements List. This form is essential to obtain delivery of all documentation. Each deliverable will be clearly specified, both description and quantity being required.

****

Technical data packages consisting of computer software and technical data (meaning technical data which relates to computer software) which are specifically identified in this project and which may be [defined][required] in other specifications must be delivered strictly in accordance with the CONTRACT CLAUSES and in accordance with the Contract Data Requirements List, DD Form 1423. Data delivered must be identified by reference to the particular specification paragraph against which it is furnished. All submittals not specified as technical data packages are considered shop drawings under the Federal Acquisition Regulation Supplement (FARS) and must contain no proprietary information and must be delivered with unrestricted rights.

1.9 PROJECT SEQUENCING

****

NOTE: Table I provides bracketed text in which the number of days between items may be specified. In many cases this information will be specified elsewhere. When project schedule is specified elsewhere remove bracketed text and Table I will provide sequencing but not specific intervals. If time intervals are to be specified here keep the bracketed text and enter the number of days in the space provided.

****

Table I outlines the sequencing of submittals as detailed in the SUBMITTALS paragraph (indicated by an 'S' in the 'TYPE' column) and activities as described in PART 3 EXECUTION (marked by an 'E' in the 'TYPE' column).

1.9.1 Sequencing for Submittals

The sequencing for submittals indicates the final date by which the submittal must be provided. After submission, the Government will review as outlined in Section 01 33 00 SUBMITTAL PROCEDURES. If the Government doesn't accept the submittal, revise the submittal and resubmit within [14][_____] days of receiving the rejection notification. Each re-submission will undergo an additional Government review, and this process will continue until the Government accepts the submittal.

1.9.2 Sequencing for Activities

The sequencing specified for activities indicates the earliest activity may begin.

****

NOTE: Table I provides bracketed text in which the number of days between items may be specified. In many cases this information will be specified elsewhere. When project schedule is specified elsewhere remove bracketed text and Table I will provide sequencing but not specific intervals. If time intervals are to be specified here keep the bracketed text and enter the number of days in the space provided.

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NOTE: If requiring a Factory Test in PART 3 EXECUTION, keep "Acceptance of Factory Test Report" in the Description column for item 1. If NOT requiring factory test keep "Notice to proceed" or edit to indicate other starting condition. Use Table I to specify the sequencing of submittals and activities. If the the project schedule has been specifiedelsewhere, remove the bracketed text, and Table I will only indicate sequencing without specific intervals. If time intervals are specified here, retain the bracketed text and input the number of days in the provided space.

****

TABLE I - PROJECT SEQUENCING

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
		Commercial contracts and Pos in place	[_____]
		Resource plan	[_____]
		Project schedule	[_____]
		Monthly progress reports	[_____]
		Kick-off meetings	[_____]
		Internal/External audit review meetings	[_____]
		Detailed functional design specification	[_____]
		Schematic Single Line Diagram	[_____]
		Equipment layout drawings	[_____]
		Studies completed and validated	[_____]
		Factory Acceptance Plan	[_____]
1		[Acceptance of Factory Test Report][Notice to proceed][_____]	[_____]
2	S	Existing Conditions Report (site assessment survey)	[_____] days after #1
3	S	Contractor Design Drawings	[_____] days after #1
4	S	Product Data Sheets and Certificate of Networthiness Documentation	[_____] days after #1
5	S	MCS IP Network Bandwidth Usage Estimate	[_____] days after #1
6	S	Pre-construction QC Checklist	[_____] days after #1
		Isolation, commissioning, testing, and restoration plans for system	[_____]
		Site readiness checklist	[_____]
7	E	Install MCS	AAO #2 thru #6
8	E	Start-Up Procedures and Start-Up Testing	ACO #7

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
9	S	Post-Construction QC Checklist	[_____] days ACO #8
10	S	Computer Software	[_____] days ACO #8
11	S	Start-Up and Start-Up Testing Report	[_____] days ACO #8
12	S	Draft As-Built Drawings	[_____] days ACO #8
13	S	PVT Phase I Procedures	[_____] days before scheduled start of #14 and AAO #11
14	E	PVT Phase I AAO #13 and #12	[_____]
15	S	PVT Phase I Report	[_____] days
16	S	Preventive Maintenance Work Plan	AAO #11
17	S	O&M Instructions	AAO #11
18	S	Basic Training Documentation	AAO #11 and [_____] days before scheduled start of #19
19	E	Basic Training (PVT Phase II)	AAO #16, #17 and #18
20	S	PVT Phase II Report	[_____] days ACO #19
21	S	Final As-Built Drawings	[_____] days AAO #20
22	S	Advanced Training Documentation	[_____] days before schedule start of #23 and AAO #18
23	E	Advanced Training ACO #19	[_____] days AAO #22, and no later than [60] days ACO #19
24	S	Refresher Training Documentation	[_____] days before #25 and AAO #18and #22
25	E	Refresher Training between	[_____] and [_____] days ACO#19 and AAO #24
26	S	Closeout QC Checklist	ACO #23

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
		Contract closure meeting	[_____]

In TABLE I the abbreviation AAO is used for 'after approval of' and 'ACO' is used for 'after completion of'.

[1.10 STANDARD MATERIALS AND PRODUCTS

****
NOTE: If the microgrid control system offers remote control or access, even if separate from an energy management control system, choose this option. Implement a Risk Management Framework (RMF) for cybersecurity. Refer to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS and UFC 4-010-06 Cybersecurity of Facility-Related Control Systems for guidance on integrating cybersecurity into the control system and for insights on the RMF process for control systems. Ensure equipment certification aligns with the Government's cybersecurity standards and interpretations.
****

Provide certification that control systems are designed and tested in accordance with DODI 8500.01, DODI 8510.01, and as required by individual Service Implementation Policy.

]1.11 QUALITY ASSURANCE AND QUALITY CONTROL

Every manufacturer of the microgrid control system and its components must implement a documented quality assurance program (QAS), which includes an inspection test plan (ITP). All suppliers, including sub-suppliers, must provide QAS and ITP documentation for all deliverables. The QAS must encompass established process control documents, either as formal procedures or work instructions. Suppliers must ensure the availability of all relevant procedures and work instructions at every work location.

Supplier's adherence to their QMS and its effectiveness will be evaluated by:

a. Ongoing output quality verifications

b. Internal and External "Hold", "Witness" "Observation" and "Review" points

c. Inspection reports of incoming parts, modular assemblies and final product

d. Company involvement in the 'non-conformance' process

e. Periodic independent quality audits

f. Performing quality inspections and tests by third parties

1.11.1 Inspection Reports

Submit inspection reports created following the ITP procedures. Provide ITP documentation to the designated authority before [planned inspection meetings][site delivery].

1.11.2 Traceability and Markings

Within the Product Data Sheets submittals, report the country of origin for all materials and equipment in the submitted traceability documentation. All test reports and certificates must clearly indicate the origin of all software and the manufacturing location of relevant goods or materials. Ensure every item, component, software, and sub-component is traceable to its origin for both software development and manufacturing.

Submit this traceability documentation within the applicable product data sheets submittals. Mark all goods and materials and trace their associated certifications throughout all processes, from engineering to construction. Ensure traceability of all sub-components through their markings to their origin and document this traceability.

1.11.3 Proof of Performance

Provide evidence of adherence to customer expectations, performance specifications, QAS requirements, IEEE 2030.8 standards, and other testing prerequisites within ITP, inclusive of [FAT][SAT][both FAT and SAT].

1.11.4 Documented ISO 9001 Compliance

Submit documentation verifying ISO 9001 Compliance Certificate for all entities in the supply chain, including engineering design firms, commissioning teams, and manufacturing teams.

1.11.5 Qualifications

Engineering and manufacturing companies participating in this microgrid must submit Installer Qualifications including evidence of having previously completed [three][five][___] projects of similar size and complexity of microgrid projects.

1.11.6 Documentation

Maintain and make accessible for review by the designated authority all QAS and ITP documentation, including changes and revisions. Including but not limited to, design documents, test reports, and quality records.

1.12 REGULATORY REQUIREMENTS

****

NOTE: Clearly define and allocate the scope of work for regulatory compliance to the contractor and construction management team in the contract documents. Recognize that this will entail effort, cost, and time.

****

Comply with all utility, local, state, and federal regulatory requirements related to this microgrid. Submit Regulatory Compliance Documentation demonstrating compliance with all utility interconnect contract stipulations. Ensure that no installation or testing done before the final SAT invalidates any warranties. Submit a table listing all regulatory requirements and confirmations of compliance. Update this list [annually][bi-annually][as required] and make it available for review when asked.

Where the microgrid couples to an external electrical grid, equip the microgrid control system with functionality required to meet the control and communication requirements of that external grid. Secure certification from the connected external grid provider or operator during the interconnect application process.

[1.12.1 [Utility Interconnect Contract]

Submit completed and approved evidence of meeting all Utility Interconnect Contract requirements. Including but not limited to [technical specifications][safety protocols][metering and telemetry][power quality standards][liability and indemnification clauses].

]1.13 DELIVERY, STORAGE, AND HANDLING

1.13.1 General Requirements

Deliver all equipment and materials in the manufacturer's original, unopened, undamaged containers with identification labels intact. Store all materials in a secure, clean, dry space in accordance with the manufacturer's instructions.

1.13.2 Handling

Handle all materials and equipment in a manner to prevent damage, adulteration, and soiling, and in accordance with the manufacturer's recommendations.

1.13.3 Storage

Store all materials and equipment off the ground and covered to protect them from weather, humidity, and temperature extremes.

1.14 SAFETY REQUIREMENTS

****

NOTE: As microgrids often integrate generation on the load side of facility transformers and operate independently from the external grid, special design consideration must be given to islanded operational states requiring dedicated grounding and protection configurations. Prior to integrating microgrids into existing installation systems, evaluate if:

Existing installation distribution equipment and switchgear are integrated.

Dedicated or modified grounding during certain conditions of operation are required.

Any islanded operational states require dedicated grounding or updated protections at any location.

****

1.14.1 Grounding and Bonding

The microgrid includes [fixed][variable] grounding system topology to accommodate various operational states. It is designed to include [a single point][multiple points] of system bonding within the microgrid boundary. Within this boundary, the grounded conductors (neutrals) are [switched][and][unswitched]. The switching mechanisms, which are [manually operated][automatically controlled], are capable of isolating the grounded conductor [at the point of common coupling][within the microgrid boundary]. [The MCS must include [monitoring][and][control] of these switching mechanisms and cease operation if grounded conductors become un-bonded to the grounding electrode system.]

1.14.2 Anti-Islanding Protection

Incorporate anti-islanding protection mechanisms in the microgrid control system (MCS) to safeguard both microgrid components and personnel. Ensure the MCS detects and disconnects the microgrid from the main grid during a grid outage, preventing unintentional islanding.

Equip the MCS with multiple methods to detect islanding conditions. These methods include, but are not limited to: [Active Frequency Drift: Monitor the system frequency and comparing it against predefined thresholds.] [Voltage Unbalance Detection: Monitor voltage levels to identify imbalances indicating an islanding condition.] [Rate of Change of Frequency (ROCOF): Track the rate of system frequency changes over time.]

Initiate a disconnect sequence within [10][20] milliseconds upon detecting an islanding condition to ensure system safety and prevent equipment damage. Do not reconnect to the main grid after an islanding event until verifying grid stability. Set a reconnection delay of at least [5][10][_____] minutes.

Coordinate anti-islanding protection with other microgrid protection mechanisms, such as over/under voltage, over/under frequency, and phase imbalance protections.

1.15 PROJECT AND SITE CONDITIONS

1.15.1 Environmental Conditions

Install the MCS [indoors][outdoors in a NEMA Type [3R][4][4X] enclosure]. Ensure each system component operates effectively in its designated environment. For MCS data communications equipment in unconditioned spaces, ensure operation within ambient temperatures of [0 and 49] [_____] degrees C [32 and 120][_____] degrees F and ambient relative humidity between 10 percent and 90 percent noncondensing. Comply with NFPA 70, UL 60950, NFPA 262, FCC EMC, and FCC Part 15 standards.

Equipment located outdoors, not provided with climate-controlled enclosure, must be capable of operating in the ambient temperature range. Electrical equipment must conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM INTERIOR DISTRIBUTION SYSTEM. Equipment and wiring must be in accordance with NFPA 70, with proper consideration given to environmental conditions such as moisture, dirt, corrosive agents, and hazardous area classification

1.15.2 Utility Interconnection Requirements

****

NOTE: Use this section where the microgrid will interconnect and provide power to an external electrical Distribution System Operator (DSO).

****

a. Ensure the microgrid control system adheres to relevant grid codes and/or the interconnection agreement with the distribution system operator (DSO).

b. Adhere to the criteria set by the interconnection agreement, which establishes the following:

    (1) The conditions under which a connection is allowed and the requirements imposed on the microgrid control system.

    (2) The financial arrangements regarding energy and power demand imports from and exports to the distribution grid, and the compensation for ancillary services provided by the microgrid.

    (3) The information required by the distribution management system (DMS) and/or the DERMS (DERMS) for monitoring and control of the microgrid.[

    (4) Provide MCS functionality to provide grid support at the point of interconnection (POI) as required by the DSO.][

    (5) Provide MCS functionality to coordinate with the DMS and/or DERMS during steady state operation and during connection, disconnection, and reconnection processes.]

    (6) Allowable parallel operation of DERs.

    (7) Allowable power and reactive power [power factor] limitations.

c. Provide required studies for Utility interconnection support. Including, but not limited to:

(1) Prior to Construction

(a) Neutral Ground Bonding, aka 'Effective Grounding & Grounding Bank Study, this to show there will be no neutral inversion under all operational modes and transitions.

(b) Transient Stability showing transition of PV from grid connected to island operation, showing the curtailment and partial shutdown of the PV during islanded operation.

(c) Equipment sizing to ensure correct sizing of transformers, conductors, gensets, circuit breakers

(2) Prior to construction:

(a) Transient stability model- showing large microgrid disturbance & DER transient response during transitions island/grid and PV paralleling

(b) Undervoltage/overvoltage ride-through

(c) Underfrequency/over-frequency ride-through

(d) Voltage stability grid connected showing Q./PF dispatch during grid connection

(e) Power dispatch during grid connection

(f) Fault study and Protective Device Coordination

(g) Clear explanation of grid connected dispatch, reconnection sequence to grid, aka 'modes of operation'

(3) Prior to energization:

(a) Validation of transient models after genset/transformer/IBR factory tests.

(b) HIL Testing with PCC, DER, and MC control and protection hardware.

(c) Factory Acceptance Test Reports demonstrating compliance with IEEE 2030.7, IEEE 2030.8, and IEEE 1547, and Interconnected Utilityrequirements.

(d) Open Phase Analysis

1.15.3 Utility Privatization Ownership Requirements

****

NOTE: If the utility assumes ownership of the final constructed microgrid, either directly or through third-party privatization, require the contractor to adhere to the following requirements.

****

1.15.3.1 Ownership

Upon initial turn-over, the microgrid and microgrid control system is anticipated to be [owned][leased][operated] by [the Government][a private entity][a public-private partnership]. Determine all ownership rights, including intellectual property associated with the microgrid control system, to be [retained by the Government][transferred to the private entity][shared between the Government and the private entity].

1.15.3.2 Coordination

Coordinate utility privatization efforts with [the local utility][and][the Government]. Ensure alignment for [interconnection][and][metering] according to [local][state][federal] regulations.

1.15.4 Existing Conditions

****

NOTE: For projects where the specified microgrid control specification will connect to existing equipment, this section is intended to be completed by the project designer of record, who is required to provide detailed information on the existing conditions relevant to the microgrid. The designer must refer to UFC 3-550-04 for technical requirements, UFC 1-300-01 for general formatting, UFC 1-300-02 for organizational structure, and IEEE 2030.7 for microgrid control systems.

Ensure that all existing conditions are thoroughly assessed and documented. This information is crucial for the contractor to understand the scope and requirements of the project.

****

1.15.4.1 External Utility Distribution System

****

NOTE: Provide details on the existing external utility distribution system, including voltage levels, fault current ratings, and any other pertinent information. Refer to UFC 3-550-04 for guidance on technical aspects.

****

[_____]

1.15.4.2 Point of Interconnection Equipment

****

NOTE: Describe the existing point of interconnection (POI) equipment, including type, ratings, and condition. This information is critical for ensuring compatibility with the new microgrid.

****

[_____]

1.15.4.3 [Description of Existing Equipment]

****
NOTE: List and describe all existing equipment that will interact with or be affected by the new microgrid. Include information such as make, model, and condition.
****

[_____]

1.15.4.4 [Description of Existing Electrical Interconnection Means]

****
NOTE: Describe the existing electrical interconnection means, including wiring, switchgear, and protection devices. Through design phase modeling:

- Validate short circuit rating of POI and downstream equipment is sufficient for fault current available under all parallel source scenarios. Ensure that the short-circuit ratings at the POI and downstream are validated for all parallel source scenarios as per UFC 3-550-04

- Confirm that the fault current available during island mode operation is sufficient to activate the protection mechanisms at the POI and downstream, in accordance with IEEE 2030.7.
****

[_____]

1.16 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

Provide MCS Operation and Maintenance Instructions which include:

a. Procedures for the MCS system start-up, operation and shut-down.

b. Final As-Built Drawings.

c. Routine maintenance checklist, arranged in a columnar format: The first column listing all installed devices, the second column stating the maintenance activity or stating that no maintenance required, the third column stating the frequency of the maintenance activity, and the fourth column providing any additional comments or reference.

d. Qualified service organization list including points of contact with phone numbers.

e. Start-Up and Start-Up Testing Report.

f. Performance Verification Test (PVT Phases I, II, & III) Procedures and Reports.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION AND OPERATIONAL REQUIREMENTS

****

NOTE: The specific microgrid topology should be based on either a distributed or central-plant architecture as outlined in UFC 3-550-04. Consider the trade-offs between leveraging existing capital asset investments and the communications intensity of the chosen architecture.

****

2.1.1 Microgrid System Architecture

The microgrid and associated MCS is designed as a [Distributed Generation Architecture with geographically disparate DERs networked at a single point of interconnection with the external distribution system][Distributed Generation Architecture with geographically disparate DERs networked at multiple points of interconnection to the external distribution system][Central-Plant Type Architecture with co-located DERs networked together and connected to the distribution system at a single point of common coupling].

Submit a detailed schematic Microgrid System Architecture Diagram that displays the layout and interconnections of all MCS components, DERs, and other interfacing systems to be connected to or controlled by the MCS. Account for the interconnection of communication networks belonging to the Government and third parties. If external grid operators require interconnection, [use redundant devices isolated from the MCS communication network][include devices within the MCS] to supply the necessary data. Communication between the MCS and third-party communications systems is [prohibited][permitted].

For each component and equipment indicated on the System Architecture Diagram, provide technical Product Data Sheets for all hardware components of the Microgrid Control System, including but not limited to controllers, Human-Machine Interface (HMI) devices, and communication equipment.

2.1.2 Microgrid Equipment

****

NOTE: As noted in UFC 3-550-04, the following considerations represent best practice and should be included as project scope allows, and elaborated further within this specification section:
*** Redundant networked sources of generation**
*** Energy Storage**
*** Bi-directional soft, Blinkless transition; From grid to island, and re-synchronized transition from island to grid**
*** Grid connected support, with capability for demand response, and ancillary services such as frequency support voltage management, and black start.**
*** Redundant (min. 2) grid-forming assets capable of supporting life safety and critical loads requiring startup time measured in seconds**
*** Redundant (min. 2) HMI visualization front-ends**
*** Redundant (min. 2) independent black start sources**

*** Load shedding capability**

****

****
NOTE: Read closely and edit the following paragraph and section describing the microgrid system interconnection and operation. Where the microgrid system is arranged such that there are multiple points of interconnection, a ring configuration for the microgrid system, or other system topology differing from that described, the following paragraph should be replaced with a system description matching the design drawings.
****

2.1.2.1 [Utility Service; Point of Common Coupling (Point of Interconnection)]

The microgrid is designed to interface with the utility grid at the designated PCC. The PCC is designed as equipped with [bi-directional metering,][fault detection relays,][and automatic reclosers] to facilitate grid interaction and ensure safety. [The MCS [must][does not] control the automatic reclosers directly.][Reclosers are controlled by the protection system. Requests for open/close are made by the MCS, and executed by the protection system.]

2.1.2.2 Power Generating Assets

****
NOTE: Refer to UFC 3-550-04 for additional guidance on selecting and configuring power generating assets. Ensure compliance with anti-islanding and other safety requirements.
****

Asset Type & ID	Firm Power Asset	Grid-Connected Operation	Island Operation	Nameplate Generation
[Diesel Generator DG-1]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]
[Solar PV SPV-1]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]
[Wind WG-1]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]
[BESS BESS-1]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]
[_____]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]

Asset Type & ID	Firm Power Asset	Grid-Connected Operation	Island Operation	Nameplate Generation
[_____]	[Yes][No]	[D][S][/E]	[D][S][/F[(___)]]	[_____]

POWER GENERATING ASSET TABLE LEGEND:

Grid-Connected Operation:

D - Disabled; Will not generate power while in grid-connected mode
S - Supporting; Grid-following Power provided in parallel to external distribution network, only when total microgrid generation is less than microgrid connected load. No power export.
P - Power Factor Correction
E - Exporting; Permitted to Export power to the external distribution network

Island Operation:

D - Disabled; Asset will not operate in island mode
F(1) - Grid-forming; optional preference indication for primary, alternate grid-forming
S - Supporting; Grid-following power provided in parallel to grid-forming asset(s)

2.1.2.3 Controlled Switches, Breakers, and Devices

****

NOTE: Refer to UFC 3-550-04 for additional guidance on the selection and configuration of controlled switches, breakers, and devices. Ensure that all devices are compatible with the MCS and meet the requirements for data acquisition, control, and safety.

****

Asset Type & ID	Asset Location	Functional Requirements	Supported Condition(s)	Connected Load (W)
[Recloser UTIL-1]	[_____]	[O][M][D]	[E][S][D][N]	[_____]
[Breaker HVAC-1]	[_____]	[O][M][D]	[E][S][D][N]	[_____]
[BESS BESS-1]	[_____]	[O][M][D]	[E][S][D][N]	[_____]

LEGEND:

Functional Requirements:

O - Operable Open and close via signal from MCS
M - Metered data provided to microgrid control system
D - Dispatchable Load; either able to increase or decrease as outlined further elsewhere

Supported Conditions

E - Essential load; supported under all modes of operation
S - Supported Load; served by microgrid, though may be shed based on programming
D - Discretionary Load; Able to be served by microgrid. Within

microgrid boundary
N - Not located within the microgrid boundary

2.1.3 Functional Requirements and Design Parameters

The microgrid control system is to enable the bounded microgrid to meet the following minimum requirements. Unless stated otherwise, the MCS must fulfill these requirements. For equipment requiring control and connected to the MCS, coordinate with the connection and communication standards detailed in this specification.

2.1.3.1 Autonomy

Ensure the MCS provides essential islanding and interconnection functions, independent of external power sources and communication networks. While economic dispatch, demand forecasting, and other optimization models can utilize external networks or services, the microgrid system controller must have fallback logic to command generation that satisfies the designated critical load.

2.1.3.2 Supported Load Profile

The microgrid is designed to be capable of serving a peak critical load of [_____] [kW][MW] during both normal and peak mission activity. Incorporate [one][multiple] grid-forming DDER asset(s) in the system to sustain this load during islanded operations, as detailed in this specification. Direct each grid-forming DER asset with variable startup instructions.

2.1.3.3 Off-grid (Island) System Endurance

The microgrid system is designed to maintain off-grid endurance for a duration of [24 hours][48 hours][3 days][7 days][_____] without the need for commercial power restoration[or DER refueling]. Integrate components such as [battery storage][fuel cells][diesel generators] to achieve this endurance requirement.

****
NOTE: Special consideration must be given to the potential reduction in fault current from the DERs in comparison to the external grid. The available current may be insufficient to appropriately clear a fault where minimal DERs are online. A design coordination study is required to ensure proper operation, and a construction-phase study will be required to confirm the design assumptions using data from selected equipment. The design must include updated coordination settings (possibly for existing to remain protection devices) at the system and device level to isolate or clear faults, preventing damage to equipment or loads. Refer to UFC 3-550-04 for additional information and requirements.
****

2.1.3.4 Energy Surety and Redundancy

Designer option - define the level of redundancy required by mission. In terms of load and redundant grid-forming or generating assets to support the critical load.

2.1.3.5 Load Shedding Requirements

[An automated load shedding strategy must be implemented to maintain the integrity of both critical and non-critical loads within the microgrid boundary. The automated load shedding must occur during specified anomalies observed [external to][or][within] the microgrid system. Load shedding must be executed under conditions such as [under-frequency,][over-frequency,][under-voltage,][over-voltage,][imbalance conditions,][DER failure,][protection system activation,][manual startup,][___].

Loads are categorized into priority levels [as indicated on the [contract][design] documents], which are defined as [Level 1: Life-Safety Systems,][Level 2: Mission-Critical Systems,][and Level 3: Non-Critical Systems]. Shedding strategies must be executed in descending order based on these levels, beginning with the least critical. Post load shedding, the MCS must automatically restore the shed loads in ascending order of priority levels, once grid stability is re-established. The restoration must be completed within [1][5][10] minutes. If sufficient generation capacity exists in island mode, either through dispatchable firm generation assets or non-dispatchable generation assets, the MCS must automatically restore shed loads based on available capacity.

The MCS must employ [deterministic][adaptive][rule-based][machine learning-based] algorithms to make shedding decisions. These algorithms must be capable of acting within [100 ms][200 ms][500 ms] from the detection of the specified anomaly.

Provide manual override function, accessible through the Human-Machine Interface (HMI), allowing for the [enabling][disabling] of load shedding and alteration of priority levels during emergencies.

Upon initiation and restoration of load shedding, designated personnel must be notified through [email][SMS][HMI alerts].][The microgrid resources are sufficient for operation of all connected loads. Automated load shedding is not required for microgrid operation.]

2.1.3.6 Restoration and Resynchronization

The MCS must restore power to critical loads within [5][10][15][20] minutes following an unplanned outage. This includes the sequence of [islanding][grid-forming] at all points of interconnection, [synchronizing][paralleling] generation assets, and [powering][restoring] designated critical loads. The restoration time is to be measured from the moment of [anomaly detection][islanding initiation] to the [restoration of the last critical load][first critical load].

Upon detecting the return of utility power at the primary side of the PCC, the system must initiate a [predefined][configurable] waiting period of [15 minutes][30 minutes][two hours][four hours][_____]. After confirming the stability of the external grid, the MCS begins execution of a soft transition, closing the [point][points] of common coupling back to the grid. Total transition duration must be no longer than [1][5][10][15] seconds. The transition must employ phase-locking and frequency matching techniques to synchronize the microgrid's [phase][frequency] with the utility's [phase][frequency]. Synchronization and connection of the soft transition is managed by the [the MCS][the protection system specified in Section 26 05 73 POWER SYSTEM STUDIES].

Provide a manual override function, available through the Human-Machine Interface (HMI) to [enable][disable] soft transitions and to alter restoration time settings. Notifications must be sent to designated personnel through [email][SMS][HMI alerts][all of the above] when transitions are initiated and when normal operations are restored.

2.1.3.7 Power System Studies

****

NOTE: The contract documents must include section 26 05 73 Power System Studies, referenced from within this paragraph. The additional requirements of those studies pertaining to the microgrid installation are included here, but may be transferred to section 26 05 73 at the designer's discretion.

****

Provide microgrid system model created using software and methods in accordance with [UFC 3-550-04][Section 26 05 73 POWER SYSTEM STUDIES]. Studies are intended to validate performance metrics of the provided equipment. In addition to the studies outlined by Section 26 05 73 POWER SYSTEM STUDIES, provide study and reports for microgrid control system in relation to voltage regulation, frequency stability, and fault response analyses.

Incorporate into the model all DERs, load profiles, and grid interaction points, such that the model is capable of simulating [steady-state][transient][both steady-state and transient] conditions. Incorporate into the model [detailed component models][simplified aggregate models][both detailed and simplified models] for DERs and loads.

Submit Power System Studies including modeled analyses reports such as [Short Circuit Study,][Coordination Study,][Arc Flash Study,][Grounding Study,][Load Flow Study,][Harmonic Analysis,][Voltage Drop Calculations,][Transient Stability Study,][and Reliability Analysis]. Validate and provide documentation of the model accuracy and performance through [field measurements][historical data][both field measurements and historical data], and discrepancies must be addressed in subsequent updates.

Upon substantial completion the microgrid system model, including all library files in their native format, unlocked and editable, must be submitted to the Government for future system analysis and upgrades.

2.1.3.8 Expandability

****

NOTE: Engineer of record is to give careful consideration to the mission and project scope goals with relation to phasing and future expansion. The microgrid system is likely to be expanded and modified over time. Consult with the Government stakeholders to determine the tolerance for outages and cost impacts as those expansions and replacements occur. In accordance with UFC 3-550-04, a modular approach will allow expansion and replacement/upgrade with minimal impact to the operations compared to a system which is installed at its maximum size and without modularity.

****

The Microgrid Control System (MCS) must be provided with a modular architecture to facilitate future expandability and scalability. This includes the ability to integrate additional DER, loads, and control algorithms without requiring a complete system overhaul.

Provide MCS hardware components, including controllers, sensors, and Human-Machine Interface (HMI) devices, such that the system is readily scalable by addition of supplemental components. Provide the complete MCS system to accommodate additional hardware through modular expansion units or through software updates. Software updated must be via [automatic][or][manual] installation [only]to improve system performance, security, and to add new features. All systems capable of upgrade must include a rollback feature, capable of reverting to previous software versions [in case of update failures]. Provide a manual override function available through the Human-Machine Interface (HMI) to [enable][disable] system expandability features during specific scenarios.

[Provide an MCS capable of integrating new DERs, including but not limited to [solar PV][wind turbines][fuel cells][battery storage][diesel generators], in a plug-and-play manner. The system must automatically recognize and configure new DERs based on pre-defined or user-configured templates.]

[The system must allow for the addition of new loads, both critical and non-critical, without requiring significant reconfiguration of the existing load management algorithms. New loads must be categorized into existing priority levels or new levels as defined by the user.]

[The MCS must support the integration of new control algorithms or updates to existing algorithms. This includes [deterministic][adaptive][rule-based][machine learning-based] algorithms for load shedding, DER optimization, and other control functions.]

[Provide an MCS system compatible with standard communication protocols such as [Modbus][DNP3][IEC 61850][OPC UA] to ensure seamless integration with new equipment and systems. Any updates or changes to communication protocols must be executed without disrupting ongoing operations.]

2.1.3.9 Real-time Data Export

The Microgrid Control System (MCS) must be capable of feeding real-time data to designated engineering analysis tools centralized within the SCADA system. The data required to be available includes, but is not limited to, system status, DER performance metrics, load profiles, and fault events. Design the MCS to support standard data exchange protocols such as [OPC UA][Modbus][DNP3] for seamless integration with the analysis tools.

2.1.3.10 Bi-Directional 'Blinkless' Transitions

Provide MCS capability to execute bi-directional "blinkless" transitions between grid-connected and islanded operational modes. Transitions are to be completed within a time window not exceeding [50 ms][100 ms][200 ms], thereby ensuring zero interruption to critical and sensitive loads.

The MCS must employ advanced control algorithms to manage the rapid disconnection and reconnection processes. These algorithms must utilize real-time measurements of voltage, frequency, and phase angle to achieve seamless transitions. Incorporate [phase-locking techniques][frequency matching techniques][both phase-locking and frequency matching techniques] to synchronize the microgrid's electrical parameters with those of the utility grid or the islanded DERs.

During the transition, the MCS must manage the ramp rates of DER to avoid sudden changes in output that could destabilize the system. The ramp rates are to be configurable and must not exceed [2%][5%][10%] of the rated power per second.

Provide a manual override function to be accessible through the Human-Machine Interface (HMI) to [enable][disable] the automated transition process. This function must be password-protected and accessible only to authorized personnel.

Upon successful completion of each transition, the MCS must log the event, capturing key parameters such as transition time, DERs involved, and any deviations from set points. Notifications are to be sent to designated personnel through [email][SMS][HMI alerts].

2.1.3.11 Demand Response and Ancillary Services

Provide MCS functionality to be capable of executing demand response actions, [both][automated][and][manual,] to modulate electrical load within the microgrid boundary in response to external grid signals or internal setpoints. The MCS is to be capable of receiving demand response commands via [OpenADR 2.0b][IEC 61850 GOOSE messages].

Provide MCS capabilities including:

[a. Load curtailment: Implementing pre-configured load shedding schemes to reduce electrical consumption upon receiving a demand response signal.]

[b. Load shifting: Temporally reallocating non-critical loads to off-peak hours.]

[c. Frequency Regulation: Continuously adjust DER output to maintain system frequency within [0.1][0.2] Hz of the nominal frequency.]

[d. Voltage Support: Control reactive power output of DERs to maintain bus voltage within [1%][2%] of nominal voltage levels.]

2.1.3.12 Island-mode Black Start Capability

The Microgrid has been designed with the capability for [operator initiated][and] [MCS automatic initiation] of a black start in island-mode operation to restore power to critical and essential loads in the absence of external grid power. The MCS is to coordinate the black start process with designated DDERs capable of self-starting without external electrical supply. These DERs include [battery energy storage systems][fuel cells][diesel generators][gas turbines].

Provide MCS capable of employing advanced control algorithms to manage voltage and frequency during the black start process. These algorithms must be capable of stabilizing the microgrid within [30 seconds][1 minute][2 minutes] from the initiation of the black start. Voltage and frequency must be maintained within [±1%][±3%][±5%] of nominal values during the entire black start process.

Provide a manual override function to be accessible through the Human-Machine Interface (HMI) to [enable][disable] the automated black start process. This function must be password-protected and accessible only to authorized personnel.

The MCS must be tested to validate its black start capability under various load and DER conditions. Select the testing to be in accordance with this specification and [IEEE 1547][IEEE 2030.8][both IEEE 1547 and IEEE 2030.8] standards.

2.1.3.13 Control System Resilience and Redundancy

Integrate resiliency and redundancy to within the MCS control algorithms and components to ensure uninterrupted operation under various failure scenarios. The system must be designed for maximum reliability, safety and integrity while maintaining an availability of [99.9%][99.99%][99.999%] or better. Notifications must be sent to designated personnel through [email][SMS][HMI alerts] upon the activation of any redundancy or failover mechanisms.

Provide the MCS such that fault tolerance is implemented at multiple levels, including but not limited to, hardware, software, and network communication. Hardware components such as controllers, data acquisition systems, and communication devices are to be configured in a redundant setup. Provide architecture supporting hot-swappable components and capable of automatic failover within [100 ms][200 ms][500 ms].

[Redundant communication paths are to be established using [ring topology][star topology][mesh topology]. In case of a communication link failure, the system is to reroute data through an alternate path within [10 ms][20 ms][50 ms].][Data integrity must be maintained through the use of [checksums][hash functions][both checksums and hash functions]. Mirror real-time data in [dual][triple] redundant databases to prevent data loss.]integrity must be maintained through the use of [checksums][hash functions][both checksums and hash functions]. Real-time data is to be mirrored in [dual][triple] redundant databases to prevent data loss.

2.1.3.14 Operational Mode Prioritization

Provide within the MCS, the ability to prioritize between efficient and resilient operational modes. The prioritization is to consider the installation location, mission requirements, and other external factors. Prioritize operational modes based on a hierarchy that aligns with mission objectives and operational constraints. This prioritization is to be configurable and adaptable to real-time conditions.

2.1.3.15 Communication with Protection System

Provide capability within MCS to maintain real-time communication with the protection system. It must be capable of sending and receiving signals related to fault detection, isolation, and system restoration. Establish seamless and secure communication between the MCS and the protection system. This communication is to be in real-time and adhere to industry-standard protocols such as IEC 61850, DNP3, or Modbus. The chosen protocol must support [unidirectional][bidirectional] data flow and be capable of transmitting both analog and digital signals.

Upon detection of a fault condition by the protection system, immediate notification must be sent to the MCS. Subsequently, the MCS must execute pre-configured actions such as load shedding, DER reconfiguration, or mode transition. All events detected by the protection system that result in a change of state or action by the MCS must be logged.

[In the event of a communication failure between the MCS and the protection system, automatically activate a backup communication channel. This backup channel must be tested periodically to ensure its functionality.]

2.1.4 Microgrid Control System Multi-Level Architecture

This section outlines the multi-level logic architecture of the Microgrid Control System (MCS), detailing the various control levels, interface components, and external communication connections. The MCS is structured into primary, secondary, and tertiary control levels, each with distinct functionalities and responsibilities. The interaction of these logic functions with the microgrid forms the basis of the MCS state control and sequences of operation and control.

2.1.4.1 MCS Primary Control (High-Speed Communications)

2.1.4.1.1 Power Flow Management

Responsible for real-time control of power flows within the microgrid, ensuring stability and reliability.

2.1.4.1.2 Fault Detection & Isolation

Detects and isolates faults within the microgrid to prevent cascading failures.

2.1.4.1.3 Operational Safety

Ensures the safe operation of all microgrid components, including adherence to safety protocols and standards.

2.1.4.1.4 Utility Requests

Handles requests from the utility for load shedding, curtailment, or other grid-supportive actions requiring immediate response.

2.1.4.1.5 State Transition Management

Manages the transitions between different operational states of the microgrid.

2.1.4.1.6 Emergency Response

Coordinates actions during emergency situations, such as natural disasters or equipment failures.

2.1.4.2 Low-Speed Communications and Control - Secondary Control

2.1.4.2.1 Load Shedding

Manages the disconnection of non-essential loads during peak demand, during faults, or for island-mode endurance in accordance with sequences of control.

2.1.4.2.2 Economic Dispatch

Near real-time optimization through the dispatch of generation resources to meet demand at the lowest cost.

2.1.4.2.3 Reactive Control

Manages the reactive power in the system to maintain voltage levels within specified limits.

2.1.4.2.4 Load Shaping

Controls load patterns to optimize energy usage and costs.

2.1.4.2.5 Voltage Control

Maintains the voltage levels within the microgrid at optimal levels by directing dispatchable generation, reactive power capable DERs, and shedding of loads.

2.1.4.3 Low-Speed Communications and Control - Tertiary Control (optimization)

2.1.4.3.1 Energy Optimization

Optimizes the energy resources to reduce costs and emissions, optimize renewable energy utilization, and ensure system resilience, through optimizing storage charging/discharging schedules, demand response, and predictive optimization based on economic or weather forecasts.

2.1.4.3.2 Grid Interaction

Manages the interactions between the microgrid and the main grid.

2.1.4.3.3 Demand Response

Coordinates with external systems for demand response events.

2.1.4.3.4 Fuel Management

Optimizes fuel usage among dispatchable generation resources.

2.1.4.3.5 Curtailment Requests

Handles requests for renewable energy curtailment.

2.1.4.3.6 HMI & Visualization

Provides human-machine interface capabilities for monitoring and control. Provides access to real-time and historical data.

2.1.4.3.7 Real-time Analytics

Performs real-time analysis of microgrid performance metrics.

2.1.4.3.8 Renewable Energy Forecasting

Predicts the availability of renewable energy resources.

2.1.4.4   MCS Physical Interface Level

2.1.4.4.1   DER Firewall

Provides cybersecurity measures to protect the MCS and interconnected systems.

2.1.4.4.2   Data Concentrators

Aggregates data from multiple sources such as remote DERs for analysis and control.

2.1.4.4.3   Protocol Converter

Converts communication protocols to ensure interoperability among different devices and systems.

2.1.4.5   MCS Connection to External Communications Systems

2.1.4.5.1   UMCS

Utility Management Control System primarily for HVAC system control, energy management, and demand response coordination.

2.1.4.5.2   SCADA

Supervisory Control and Data Acquisition system for real-time monitoring and control.

2.1.4.5.3   External Grid Operator

Coordinates with the larger grid for import/export of power and other grid services.

2.1.4.5.4   Distributed Energy Resource Management System (DERMS)

Manages the distributed energy resources within the microgrid.

2.1.4.6   Protection & Metering Interfaced with MCS

2.1.4.6.1   Remote I/O

****

NOTE: Select the design option where remote monitoring is permitted. Segregation of control and remote monitoring prevents attacks paths to the microgrid control loop from remote monitoring stations if control is not mandatory.

****

Remote input/output modules for data acquisition and control. [For remote monitoring purposes an out-of-bounds monitoring must be installed physically isolated from the control loop metering.]

2.1.4.6.2   Meters, PQM

Power Quality Meters for monitoring voltage, current, and other electrical parameters.

2.1.4.6.3 Protective Relays

Devices that detect faults and trigger circuit breakers.

2.1.4.7 Microgrid Assets Controlled by MCS

2.1.4.7.1 External Grid PCC

Point of Common Coupling with the external grid.

2.1.4.7.2 Grid-Forming DER(s)

DERs capable of forming a grid. Typically, firm-generation assets.

2.1.4.7.3 Grid-Following DER(s)

Distributed Energy Resources that follow the grid. Typically, inverter-based assets.

2.1.4.7.4 ESS

Energy Storage Systems for storing excess energy.

2.1.4.7.5 Dispatchable Load(s)

Loads that can be controlled or shed as needed.

2.1.4.7.6 Controllable Load(s)

Loads that can be modulated or shifted for demand response or other grid services.

Operational States and State Sequences of Control (Control Algorithms) Provide MCS capable of managing the following operational states at a minimum. For each state, in order to execute the listed sequences of control, the MCS is responsible for closed loop control of the [generating assets,][DERs,][breakers and switches,][reclosers,][generation and load dispatch,][and sending and receiving control signals and data for external systems].

2.1.4.8 State I: Normal Operation (Grid-Tie Mode, Standby)

In this state, the MCS must maintain grid-connected operations while on standby for contingency scenarios. Ensure the system is prepared for immediate transition to other operational states as programmed or directed.

2.1.4.8.1 MCS Primary Control (high-speed)

a. Power Flow Management: Continuously monitor and control power flows to maintain grid stability.
b. Can initiate soft transition to Island Mode (SOO-101).
c. Can initiate Peak Shaving (SOO-101).
d. Fault Detection & Isolation: Continuously monitor for electrical faults and be prepared to isolate faulted sections.
e. Can initiate Fault Isolation (SOO-002).
f. Operational Safety: Ensure all safety protocols are active and operational.
g. Can initiate Emergency Shutdown (SOO-003).
h. Utility Requests: Standby to receive and act upon utility requests for

grid services.

i. Can trigger Demand Response (SOO-004).
j. Can initiate Grid Support Services (SOO-102).
k. State Transition Management: Maintain readiness for state transitions based on system conditions or external commands.
l. Responsible for executing all state transitions (SOO-001).
m. Responsible for initiating Blackout Response (SOO-006)
n. Allowable State Transition Sequence: Grid-Tie to Island Forming (SOO-1x2)
o. Allowable State Transition Sequence: Grid-Tie to Testing (SOO-1x6)
p. Allowable State Transition Sequence: Grid-Tie to Blackout (SOO-1x3)
q. Emergency Response: Standby for emergency response activation, including natural disasters or equipment failures.
r. Can initiate Emergency Response Protocol (SOO-005).
s. Can initiate Communications Failure Response (SOO-007)

2.1.4.8.2 MCS Secondary Control (low-speed)

a. Load Shedding: Monitor load levels and be prepared for non-essential load shedding.
b. Can initiate Grid-tied Load Shedding Protocol (SOO-103).
c. Can initiate Peak Shaving (SOO-104).
d. Economic Dispatch: Maintain an optimized dispatch schedule for generation resources.
e. Reactive Control: Monitor reactive power levels and control VAR compensation devices.
f. Load Shaping: Monitor and control load patterns for optimal energy usage.
g. Voltage Control: Monitor and maintain voltage levels within specified limits.
h. Can initiate Voltage Regulation (SOO-105).

2.1.4.8.3 MCS Tertiary Control (long-term optimization)

a. Energy Optimization: Standby to optimize energy resources based on predictive algorithms.
b. Can trigger Energy Optimization Protocol (SOO-106).
c. Grid Interaction: Monitor the status of the main grid and be prepared for transitions.
d. Can initiate Grid Support Services (SOO-102).
e. Demand Response: Standby for demand response events from the utility or other external systems.
f. Can initiate Demand Response (SOO-108).
g. Fuel Management: Monitor fuel levels for dispatchable generators.
h. Curtailment Requests: Standby to receive and act upon renewable energy curtailment requests.
i. Can initiate Renewable Curtailment (SOO-109).
j. HMI & Visualization: Ensure real-time and historical data are available for monitoring.
k. Perform real-time analytics for system performance.
l. Provide Renewable Energy Forecasting: Standby with updated renewable energy forecasts.

2.1.4.8.4 MCS Physical Interface Level

a. DER Firewall: Ensure cybersecurity measures are active.
b. Data Concentrators: Aggregate data from DERs for system analysis.
c. Protocol Converter: Ensure all communication protocols are operational for device interoperability.

2.1.4.8.5 MCS Connection to External Communications Systems

a. UMCS: Standby for HVAC control and energy management commands.
b. Can trigger HVAC Optimization (SOO-110).
c. SCADA: Ensure real-time data is being sent to and received from the SCADA system.
d. External Grid Operator: Standby for commands or data exchange with the external grid operator.
e. DERMS: Ensure DERs are being managed according to set parameters.

2.1.4.8.6 Protection & Metering Interfaced with MCS

a. Remote I/O: Ensure data acquisition and control signals are operational.
b. Meters, PQM: Continuously monitor power quality parameters.
c. Protective Relays: Monitor status for connected protective relays; ensure they remain operational and ready to act upon fault conditions.
d. Can initiate Fault Isolation (SOO-003).

2.1.4.8.7 Microgrid Assets Controlled by MCS

a. External Grid PCC: Monitor the point of common coupling with the external grid for any anomalies.
b. Grid-Forming DER(s): Ensure grid-forming DERs are operational and synchronized.
c. Grid-Following DER(s): Ensure grid-following DERs are operational and synchronized.
d. ESS: Monitor the state of charge and health of energy storage systems.
e. Can initiate Energy Storage Dispatch (SOO-006).
f. Dispatchable Load(s): Ensure dispatchable loads are controllable and monitor their status.
g. Controllable Load(s): Monitor and control controllable loads for demand response or other grid services.
h. Can be part of Demand Response (SOO-004).

2.1.4.9 State 2: Isolation from External Utility (Islanding; Transient State)

Upon detection of an external utility failure or other triggering events, the MCS must initiate the transition to islanding mode. Breakers or reclosers at the point(s) of common coupling (PCCs) must be opened, and system boundaries established.

2.1.4.9.1 MCS Primary Control (high-speed)

a. Power Flow Management: Responsible for real-time control of power flows within the islanded microgrid, ensuring stability and reliability. Temporarily suspends non-urgent control actions; focuses on stabilizing power flows during the transition.
b. Initiates Black Start Protocol (SOO-201)
c. Fault Detection & Isolation: Detects and isolates faults within the islanded microgrid to prevent cascading failures.
d. Operational Safety: Validates safety protocols specific to the transition to island mode.
e. Utility Requests: Suspends handling of new utility requests; maintains ongoing actions.
f. State Transition Management: Actively manages the transition to island mode.

g. Completes ongoing state transitions (SOO-001).
h. Allowable State Transition Sequence: Islanding to MG Formation (SOO-2x3).
i. Emergency Response: Continues to monitor for emergency situations that may arise during the transition. Coordinates actions during emergency situations specific to the islanded state.

2.1.4.9.2 MCS Secondary Control (low-speed)

a. Load Shedding: Prepares for potential load shedding; suspends non-urgent shedding actions. [Manages the disconnection of non-essential loads for island-mode endurance.]
b. Initiates Island Load Shedding (SOO-202) to maintain stability of mirogrid system
c. Economic Dispatch: Temporarily suspends optimization
d. Reactive Control: Manages the reactive power in the islanded system to maintain voltage levels.
e. Load Shaping: Suspends load shaping activities.
f. Voltage Control: Prepares for voltage control in island mode; suspends non-urgent actions. Maintains the voltage levels within the islanded microgrid by directing dispatchable generation and reactive power capable DERs.

Initiates Generation Synchronization (SOO-203).

2.1.4.9.3 MCS Tertiary Control (long-term optimization)

a. Energy Optimization: Suspends long-term optimization activities.
b. Grid Interaction: Prepares for disconnection from the main grid.
c. Demand Response: Suspends new demand response events; maintains ongoing events.
d. Fuel Management: Pauses economic fuel optimization actions.
e. Curtailment Requests: Suspends new curtailment requests; maintains ongoing curtailments.

2.1.4.9.4 MCS Physical Interface Level

a. DER Firewall: Maintains current cybersecurity measures; prepares for island-specific measures.
b. Data Concentrators: No functional change.
c. Protocol Converter: No functional change.

2.1.4.9.5 MCS Connection to External Communications Systems

a. UMCS: Suspends new HVAC control actions; maintains ongoing actions.
b. SCADA: Prepares for island-mode operation; maintains essential real-time data exchange.

2.1.4.9.6 Protection & Metering Interfaced with MCS

a. Remote I/O: Maintains essential data acquisition; suspends non-urgent control signals.
b. Meters, PQM: Focuses on essential power quality parameters; suspends detailed monitoring.
c. Protective Relays: Maintains current operational status; prepares for island-specific settings.

2.1.4.9.7 Microgrid Assets Controlled by MCS

a. External Grid PCC: Monitors for safe disconnection; prepares for island mode. Monitors for reconnection readiness.

b. Grid-Forming DER(s): Prepares for grid-forming operations; provides synchronization coordination for connected DERs. .
c. Grid-Following DER(s): Suspends new actions; maintains current operational status for soft transition. [Directs grid-following DERs offline for black start]
d. ESS: Prepares for island-mode dispatch; maintains current state of charge.
e. Dispatchable Load(s): Prepares for potential shedding or control; maintains current status based on load forming logic.
f. Controllable Load(s): Suspends new control actions; maintains current operational status based on load shedding logic.

2.1.4.10 State 3: Microgrid Formation (Soft Transition or Black Start)

In the event of unplanned grid failure with no energized generation resources, the MCS must initiate a black start. Initialize the system process to synchronize all resources uniformly to a defined reference frequency.

2.1.4.10.1 MCS Primary Control (high-speed)

a. Power Flow Management: Finalizes transition to island mode; ensures stable power flows.
b. Initiates Soft Transition Completion (SOO-301) or Black Start Completion (SOO-302) as applicable.
c. Fault Detection & Isolation: Resumes full fault detection and isolation capabilities.
d. Operational Safety: Validates and enforces island-mode safety protocols.
e. Utility Requests: Resumes handling of utility requests in island mode. If Island mode entered at utility request, monitors for change in state of request.
f. State Transition Management: Confirms successful transition to island mode.
g. Can initiate State Transition to Island Mode (SOO-001).
h. Allowable State Transition Sequence: MG Formation to Island Mode (SOO-3x4)
i. Allowable State Transition Sequence: MG Formation to Grid-Connect (SOO-3x5) (typically following black start where external grid source is available.)
j. Emergency Response:

2.1.4.10.2 MCS Secondary Control (low-speed)

a. Load Shedding: Resumes normal load shedding protocols specific to island mode.
b. Initiates Island Load Confirmation (SOO-303).
c. Economic Dispatch: Resumes economic dispatch optimized for island mode.
d. Reactive Control: Resumes full reactive power control.
e. Load Shaping: Resumes load shaping activities optimized for island mode.
f. Voltage Control: Resumes full voltage control capabilities.
g. Initiates Island Voltage Stabilization (SOO-304).

2.1.4.10.3 MCS Tertiary Control (long-term optimization)

a. Energy Optimization: Resumes long-term optimization activities specific to island mode.

b. Grid Interaction: Monitors for potential reconnection to the main grid.
c. Demand Response: Resumes demand response activities optimized for island mode.
d. Fuel Management: Resumes fuel optimization activities.
e. Curtailment Requests: Resumes handling of curtailment requests in island mode.

2.1.4.10.4 MCS Physical Interface Level

a. ER Firewall: Activates island-specific cybersecurity measures.
b. Data Concentrators: Resumes full data aggregation capabilities.
c. Protocol Converter: Activates island-specific communication protocols.

2.1.4.10.5 MCS Connection to External Communications Systems

a. UMCS: Resumes full HVAC control and energy management activities.
b. SCADA: Resumes full real-time data exchange capabilities.

2.1.4.10.6 Protection & Metering Interfaced with MCS

a. Remote I/O: Resumes full data acquisition and control capabilities.
b. Meters, PQM: Resumes full monitoring of power quality parameters.
c. Protective Relays: Activates island-specific settings and resumes full operational status.

2.1.4.10.7 Microgrid Assets Controlled by MCS

a. External Grid PCC: Confirms successful disconnection and monitors for reconnection criteria.
b. Grid-Forming DER(s): Confirms successful transition to grid-forming operations.
c. Grid-Following DER(s): Resumes normal operations in island mode.
d. ESS: Confirms state of charge and resumes normal dispatch activities.
e. Dispatchable Load(s): Resumes full controllability.
f. Controllable Load(s): Resumes normal control activities optimized for island mode.

2.1.4.11 State 4: Islanded Operation (Optimized Operation for Resilience and Endurance)

Once full load is served, the MCS must optimize operation by managing load factors of paralleled generation, paralleling inverter-based generation devices, and shedding discretionary loads to increase system endurance.

2.1.4.11.1 MCS Primary Control (high-speed)

a. Power Flow Management: Maintains stable power flows within the islanded microgrid.
b. Initiates Load Balancing (SOO-401).
c. Fault Detection & Isolation: Continuously monitors for electrical faults and isolates faulted sections.
d. Initiates Island Fault Isolation (SOO-402).
e. Operational Safety: Enforces island-mode safety protocols.
f. Utility Requests: Not applicable in island mode.
g. State Transition Management: Monitors conditions for potential reconnection to the main grid.
h. Initiates Reconnection Pre-check (SOO-403).
i. Allowable State Transition Sequence: Island Mode to Grid Connect (SOO-4x5)

j. Emergency Response: Maintains readiness for emergency scenarios specific to island mode.

2.1.4.11.2 MCS Secondary Control (low-speed)

a. Load Shedding: Manages load shedding specific to island mode.
b. Initiates Island Load Shedding (SOO-404).
c. Economic Dispatch: Optimizes dispatch of generation resources within the island.
d. Reactive Control: Manages reactive power to maintain voltage levels.
e. Load Shaping: Controls load patterns to optimize energy usage in island mode.
f. Voltage Control: Maintains voltage levels within specified limits.
g. Initiates Island Voltage Regulation (SOO-405).

2.1.4.11.3 MCS Tertiary Control (long-term optimization)

a. Energy Optimization: Optimizes energy resources based on island-mode constraints.
b. Initiates Island Energy Optimization (SOO-406).
c. Grid Interaction: Not applicable in island mode.
d. Demand Response: Manages demand response events within the island.
e. Initiates Island Demand Response (SOO-407).
f. Fuel Management: Optimizes fuel usage among dispatchable generation resources.
g. Initiates Island Fuel Management (SOO-408).
h. Curtailment Requests: Manages renewable energy curtailment within the island.
i. Initiates Island Renewable Curtailment (SOO-409).

2.1.4.11.4 2.1.6.11.4 MCS Physical Interface Level

a. DER Firewall: Maintains island-specific cybersecurity measures.
b. Data Concentrators: Aggregates data for island-mode analysis and control.
c. Protocol Converter: Maintains island-specific communication protocols.

2.1.4.11.5 MCS Connection to External Communications Systems

a. UMCS: Manages HVAC and energy in island mode.
b. SCADA: Ensures real-time data exchange within the island.

2.1.4.11.6 Protection & Metering Interfaced with MCS

a. Remote I/O: Maintains data acquisition and control signals.
b. Meters, PQM: Continuously monitors power quality parameters in island mode.
c. Protective Relays: Operates with island-specific settings.

2.1.4.11.7 Microgrid Assets Controlled by MCS

a. External Grid PCC: Monitors for reconnection criteria to the main grid.
b. Grid-Forming DER(s): Operates to maintain grid stability.
c. Grid-Following DER(s): Follows the grid-forming DERs.
d. ESS: Manages state of charge and dispatch activities.
e. Dispatchable Load(s): Manages controllability based on island-mode requirements.
f. Controllable Load(s): Manages control activities specific to island mode.

2.1.4.12 State 5: Re-Synchronization Back to External Utility (Soft Transition Only; Transient State)

Upon detecting the return of stable utility power, the MCS must wait for a predefined period to confirm utility stability before initiating a soft transition back to commercial power.

2.1.4.12.1 MCS Primary Control (high-speed)

a. Power Flow Management: Prepares the system for reconnection by aligning voltage, frequency, and phase.
b. Initiates Reconnection Pre-check (SOO-501).
c. Fault Detection & Isolation: Ensures no faults exist that would prevent reconnection.
d. Initiates Reconnection Safety Check (SOO-502).
e. Operational Safety: Validates that all safety protocols for reconnection are met.
f. Initiates Safety Confirmation (SOO-503).
g. Utility Requests: Awaits clearance from the utility for reconnection.
h. State Transition Management: Executes the reconnection sequence.
i. Initiates Reconnection Sequence (SOO-504).
j. Allowable State Transition Sequence: Re-sync to Grid-Tie Mode (SOO-5x1)
k. Allowable State Transition Sequence: Re-sync to Island Mode (SOO-5x4) (upon resync failure)
l. Emergency Response: Stands by for any emergency scenarios during reconnection.

2.1.4.12.2 MCS Secondary Control (low-speed)

a. Load Shedding: Prepares for potential load adjustments upon reconnection.
b. Economic Dispatch: Plans for dispatch adjustments that occur post-reconnection.
c. Reactive Control: Prepares reactive power compensation for reconnection.
d. Load Shaping: Plans for load adjustments upon reconnection.
e. Voltage Control: Aligns voltage levels for reconnection.

2.1.4.12.3 MCS Tertiary Control (long-term optimization)

a. Energy Optimization: Plans for energy resource adjustments post-reconnection.
b. Grid Interaction: Prepares for interactions with the main grid post-reconnection.
c. Demand Response: Prepares for potential demand response events post-reconnection.
d. Fuel Management: Plans for fuel usage adjustments post-reconnection.

2.1.4.12.4 MCS Physical Interface Level

a. DER Firewall: Validates cybersecurity protocols for reconnection.
b. Data Concentrators: Aggregates data for reconnection analysis and control.
c. Protocol Converter: Validates communication protocols for reconnection.

2.1.4.12.5 MCS Connection to External Communications Systems

a. UMCS: Prepares for HVAC and energy management post-reconnection.

b. SCADA: Validates real-time data exchange capabilities for post-reconnection.

2.1.4.12.6 Protection & Metering Interfaced with MCS

a. Remote I/O: Validates data acquisition and control signals for reconnection.
b. Meters, PQM: Validates power quality parameters for reconnection.
c. Protective Relays: Validates settings for reconnection.

2.1.4.12.7 Microgrid Assets Controlled by MCS

a. External Grid PCC: Validates criteria for reconnection to the main grid.
b. Grid-Forming DER(s): Prepares for transition to grid-following mode.
c. Grid-Following DER(s): Prepares for synchronization with the main grid.
d. ESS: Prepares for state of charge and dispatch activities post-reconnection.
e. Dispatchable Load(s): Prepares for controllability adjustments post-reconnection.
f. Controllable Load(s): Prepares for control activities post-reconnection.

2.1.4.13 State 6: Testing and Diagnostic State

This mode supports regularly scheduled loaded testing, device testing, and troubleshooting. The MCS must be capable of transitioning to this state for diagnostic and testing purposes. Individual components may be taken out of service for testing as operations and safety procedures allow. Protective functions must never be permitted to be taken out of service while the devices remain energized without a local failsafe controller. At a minimum, testing state must provide for testing of microgrid control system components and functions without interruption to regular operations.

[Loaded Testing: _____]
[Device Testing: _____]
[Isolation Testing: _____]

2.1.5 Microgrid Control System Sequences of Control

This section outlines the Sequences of Control (SOCs) that govern the behavior of the Microgrid Control System (MCS) under various conditions and operational states. The sequences of control defined are included to communicate design intent for functionality and operation and do not explicitly cover each interaction of grid components, features of the necessary communication, timing required, or the means of executing the functions described.

The SOCs are categorized based on their function and the operational state from which they are typically initiated:

a. Sequences beginning with '0' (e.g., SOC-001, SOC-002, etc.): These are general sequences that typically may be executed from any operational state.
b. Sequences with a leading numeral '1-6' (e.g., SOC-102, SOC-203, etc.): These sequences are typically initiated from the operational state represented by the leading numeral. For example, SOC-102 would generally be initiated from operational state '1', Normal Grid-Tie Operation.

c. Sequences with an 'x' in the second position (e.g., SOC-1x2, SOC-2x1, etc.) are state transition sequences, guiding the system from one operational state to another in a controlled manner.

2.1.5.1 SOC-001: State Transition

A macro sequence of operation; the Microgrid Control System (MCS) transitions between various operational states such as grid-connected, islanded, and testing modes as outlined above. The transition logic is based on real-time data and pre-defined conditions. The MCS must be capable of execute the state transitions based on [manual operator input][automated logic][pre-set schedules].

2.1.5.2 SOC-002: Fault Isolation

In this sequence, the Microgrid Control System (MCS) transitions between various operational states such as grid-connected, islanded, and emergency modes. The transition logic is based on real-time data and pre-defined conditions. The MCS must execute this sequence based on [manual operator input][automated logic][pre-set schedules].

2.1.5.3 SOC-003: Emergency Shutdown

In extreme conditions requiring immediate shutdown, the MCS must execute a controlled shutdown sequence to protect both hardware and personnel. This includes [disconnecting non-essential loads][shutting down generation units][activating emergency response protocols].

2.1.5.4 SOC-004: Demand Response

The MCS must adjust generation and load profiles in real-time to meet demand-side management objectives. This could be triggered by [utility signals][peak pricing periods][manual operator input].

2.1.5.5 SOC-005: (External) Emergency Response

In the event of an emergency such as a natural disaster, the MCS must switch to a pre-defined emergency response mode. This involves [prioritizing critical loads,][prioritizing island mode endurance,][isolating faulted or impacted system components,][utilizing generation sources to meet mission requirements,][_____].

2.1.5.6 SOC-006: Blackout Response

In this sequence of operation, the microgrid has been subjected to a planned or unplanned utility outage and loss of utility power. [Immediately after the loss of utility,][The MCS must wait for a delay of [_____] seconds for the return of a stable utility source, after which] the MCS must [automatically] begin the Black-Start Microgrid Formation Sequence of Operation.

2.1.5.7 SOC-007: Communications Failure Response

Upon loss of communication with the central control, the MCS must switch to a fail-safe mode, maintaining essential services using local control logic. This could involve [manual control][pre-loaded algorithms][local sensor data].

2.1.5.8 SOC-100: Normal Grid-tie Mode Stable Operation

The microgrid is operating in a stable, grid-connected mode. The MCS must manage the generation assets and loads to maintain optimal power quality and system efficiency. This involves [real-time monitoring][load forecasting][reactive power compensation].

2.1.5.9 SOC-101: Soft transition to Island Mode

[The microgrid system controller must not perform a seamless, loaded transition from grid-connected to island mode.][The microgrid system controller will perform a seamless transition of [only essential][all connected] loads from grid-connected to island mode. Prior to opening the [switch(es)][recloser(s)][breaker(s)] at the point of common coupling to transition into island mode, all non-essential loads exceeding the generation and step capacity of the microgrid firm power generation assets must be shed.]

May be initiated by the monitoring losing faith in the connected external grid; parameters outside IEEE 1547.8 requirements for anti-islanding, minimum voltage ride-through, under and over-voltage trip time.

2.1.5.10 SOC-102: Grid Support Services

During this Sequence of Operation (SOC), the Microgrid Control System (MCS) actively engages in supporting the stability and reliability of the connected utility grid. The MCS must [continuously monitor][periodically scan] grid parameters such as frequency, voltage, and phase angle. Based on real-time analytics and pre-defined setpoints, the MCS must [automatically adjust][request operator confirmation to adjust] the output of grid-forming DERs to provide ancillary services. These services include [frequency regulation,][voltage support,][reactive power compensation,][and demand response]. [The MCS may also engage in [demand response][energy arbitrage][frequency regulation] [as directed by an external DERMS][based on real-time grid conditions].]

[a. Frequency Regulation: The MCS must [automatically][manually] adjust the output of grid-forming DERs to maintain grid frequency within specified limits.]

[b. Voltage Support: Utilizing advanced control algorithms, the MCS must [dynamically adjust][maintain] the reactive power output of DERs to support grid voltage levels.]

[c. Reactive Power Compensation: The MCS must [automatically compensate][provide options to human operator for compensating] reactive power imbalances in the grid by controlling the VAR output of DERs.]

[d. Demand Response: Upon receiving signals or setpoints from the utility or an authorized entity, the MCS must execute pre-defined load shedding or load shifting strategies.]

2.1.5.11 SOC-103: Grid-tied Load Shedding

When the main grid is under stress, the MCS must execute a load-shedding sequence to alleviate the strain by [prioritizing essential loads,][disconnecting non-essential loads,][modulating grid-parallel generation,][_____].

2.1.5.12 SOC-104: Peak Shaving

During peak demand periods, the MCS must optimize the generation and load profile to minimize peak demand charges by means of [utilizing energy storage][demand-side management][load shifting].

2.1.5.13 SOC-105: Voltage Regulation

The MCS is requried to continuously monitor the voltage levels within the microgrid and exert control and direction for components within the microgrid boundary, ensuring the utilization voltage remains within the acceptable range defined by IEEE 1547.

2.1.5.14 SOC-106: Energy Optimization

In this sequence, the MCS must optimize the energy flow within the microgrid to achieve maximum efficiency and reliability based on [signals from DERMS external to the MCS,][real-time pricing data,][historical and projected load profiles,][renewable or dispatchable generation availability].

2.1.5.15 SOC-108: Demand Response

Upon receiving a utility load shed request, the MCS must prioritize loads based on predefined criteria and execute a shedding sequence to reduce total system load.

As directed by the system ['s participation in Voluntary Protection Program][operator] [automated logic], the MCS begins the process to transition from grid-tied mode to island mode. Where the islanded microgrid is insufficient to support all connected and powered loads with dispatchable generation resources and firmed renewable generation, the excess loads are disconnected from the distribution system by the MCS. After stabilization and paralleling of a Grid-forming asset, the MCS directs the breaker(s) or recloser(s) at the point of common coupling to open forming the boundaries of the microgrid. Upon transition, the microgrid control system enters island mode operation and exerts control over all devices, energy resources, and loads.

2.1.5.16 SOC-109: Renewable Curtailment

Upon receipt of a renewable curtailment request from the utility, the MCS must adjust the output of renewable generation sources to meet the requested curtailment levels.

2.1.5.17 SOC-110: HVAC Optimization

2.1.5.18 SOC-111: Directed Grid Disconnect

As directed by the system ['s participation in Voluntary Protection Program][operator] [automated logic], the MCS begins the process to transition from grid-tied mode to island mode. Where the islanded microgrid is insufficient to support all connected and powered loads with dispatchable generation resources and firmed renewable generation, the excess loads are disconnected from the distribution system by the MCS. After stabilization and paralleling of a Grid-forming asset, the MCS directs the breaker(s) or recloser(s) at the point of common coupling to open forming the boundaries of the microgrid. Upon transition, the microgrid control system enters island mode operation and exerts control over all devices, energy resources, and loads.

2.1.5.19 SOC-201: Black Start

Typically initiated following a planned or unplanned outage of the external grid, the MCS orchestrates a black start procedure to energize the microgrid. Leveraging black start-capable DER(s), the MCS ensures that the initial voltage and frequency are within acceptable limits before permitting additional resources online. The MCS also validates that the renewable sources, if any, adhere to IEEE 1547 Clause 8 requirements for anti-islanding and ride-through capabilities.

2.1.5.20 SOC-202: Island Load Shedding

Operating in Island-forming state, and upon detecting an imbalance between generation and load, the system immediately [engages in load shedding protocols][and directs dispatchable generation startup or ramp-up]. Priority is given to maintaining power to critical infrastructure, as per pre-defined load hierarchies.

2.1.5.21 SOC-203: Generation Synchronization

The MCS executes phase alignment algorithms to synchronize all active generators. This ensures cohesive operation and minimizes phase imbalances. If renewable energy sources are part of the generation mix, their variable output is stabilized to align with other generators. Operations are returned to the originating state upon completion of this SOC.

2.1.5.22 SOC-301: Soft Transition Completion

Transitioning into the 'Microgrid Formation' state from a Grid-Tie state, the MCS adjusts the microgrid's phase, frequency, and voltage to stabilize the islanded microgrid. This soft transition aims to minimize any disruptions to connected loads during the islanding process.

2.1.5.23 SOC-302: Black Start Completion

Once a successful black start is achieved, the MCS validates the stability and readiness of all connected resources. It then transitions the system to an 'Islanded Operation' state, ensuring that the microgrid is fully capable of supporting the designated critical load.

2.1.5.24 SOC-400: Island Mode Stable Operation

In this state the [Diesel generator(s)][_____] operates [in parallel] to provide the grid-forming voltage and frequency. During normal Island Mode [excess generation must be diverted to the ESS][excess generation must be curtailed. The MCS must provide direction to curtail production to the connected DERs][, and the MCS will direct breakers and switches supporting non-essential loads to open based upon available generation and load management]. The MCS must direct non-essential loads be shed where the demand load exceeds the firm generation capacity.

2.1.5.25 SOC-401: Load Balancing

Operating in Island mode, the MCS Utilizes real-time data to dynamically direct or connect/disconnect loads and provide direction to various dispatchable DERs and energy storage systems or connect/disconnect them based on their current capacity and efficiency. This sequence is occurring and repeating.

2.1.5.26 SOC-402: Island Fault Isolation

Should a fault occur within the islanded microgrid, automated fault detection sequence must initiate automatically. The MCS must isolate the faulty sections and reroute power to maintain microgrid stability, intended on preventing cascading failures and maintaining support of critical loads.

2.1.5.27 SOC-403: Reconnection Pre-check

Before initiating the reconnection to the main grid, a series of checks are conducted on both the microgrid and utility source. These include utility stability analysis for a specified duration, microgrid-to-utility phase matching, voltage matching, and frequency sync. Only after successful completion and evaluation within acceptable parameters, the MCS is to proceed with the reconnection sequence.

2.1.5.28 SOC-404: Island Load Shedding

To prevent overloading of DERs, the MCS is requried to engage automated load-shedding algorithms. Non-critical loads must be disconnected based on priority levels, ensuring that essential services remain uninterrupted.

2.1.5.29 SOC-405: Island Voltage Regulation

Voltage levels are continuously monitored. If any deviation from the specified limits is detected, the MCS must [activate capacitor banks,][direct on-load tap changers,][command ESS to charge or discharge as reactive power source or sink,][direct dispatchable or sheddable loads,][and][control reactive power from inverters] to maintain stable voltage levels.

2.1.5.30 SOC-406: Island Energy Optimization

Beginning in Island Mode, the MCS immediately assesses the current power flow, including generation assets, storage status, and load profiles. It then prioritizes renewable energy sources, directing them to operate at their maximum efficiency levels. Concurrently, the MCS adjusts the charge or discharge rates of Energy Storage Systems (ESS) to either store excess energy or release stored energy to meet demand. If renewables and ESS are insufficient, the MCS must provide direction to ramp up dispatchable generation assets, [gas turbines][and][diesel generators][___][] to meet demand. The MCS also [engages in real-time load forecasting to anticipate future energy needs][receives signals from external DERMS based on real-time load projection], adjusting generation and storage operations accordingly. Throughout this sequence, the MCS continuously monitors the state of charge of the ESS and the fuel levels of dispatchable generators to ensure long-term endurance to meet mission requirements.

2.1.5.31 SOC-407: Island Demand Response, Dispatchable Generation & Consumption

The MCS, referencing the defined and programmed categorization of loads into [critical,][essential,][and non-essential], and prepares to shed loads in inverse priority if necessary. Simultaneously, the MCS sends signals to dispatchable loads and generation assets, instructing them to either ramp up or down based on current needs. [Alternatively, it may instruct dispatchable generators to increase output.]

2.1.5.32 SOC-408: Island Fuel Management

Fuel levels and consumption rates for non-renewable DERs are closely monitored. Should fuel levels approach critical limits, the MCS must trigger alerts and may switch to alternative sources to maintain power supply.

2.1.5.33 SOC-409: Island Renewable Curtailment

When supply from renewable sources exceeds demand, the MCS must curtail the excess generation. This is crucial for maintaining microgrid stability and preventing potential damage to infrastructure.

2.1.5.34 SOC-501: Reconnection Pre-check

Before initiating the reconnection to the main grid, a series of checks are conducted on both the microgrid and utility source. These include utility stability analysis for a specified duration, microgrid-to-utility phase matching, voltage matching, and frequency sync. Only after successful completion and evaluation within acceptable parameters, the MCS is to proceed with the reconnection sequence.

2.1.5.35 SOC-502: Reconnection Safety Check

Prior to closing the point of common coupling circuit, the MCS directs a series of final checks [and simulations] [and directs protection system updates, shifting from island mode to grid-tie mode protection settings].

2.1.5.36 SOC-503: Safety Confirmation

In this sequence, the MCS sends a safety confirmation signal to both local operators and the utility grid control center. This serves as the final go/no-go decision point for reconnection. The MCS waits for an acknowledgment signal from the utility grid control center, confirming that it is safe to proceed with the reconnection. If the acknowledgment is not received within a predefined time, the MCS aborts the reconnection and reverts to island mode, ensuring the safety and integrity of the microgrid.

2.1.5.37 SOC-504: Reconnection Sequence

With all safety checks complete and confirmations received, the MCS initiates the final reconnection sequence. It first synchronizes the microgrid's voltage, frequency, and phase angle with those of the external grid. Once synchronized, the MCS closes the PCC breakers, effectively transitioning the microgrid from island mode to grid-tied operation. The MCS then gradually ramps down or shuts off internal generation assets as it begins to draw power from the external grid. Finally, the MCS performs a post-connection assessment to ensure that all systems are stable and operating as expected, completing the transition back to grid-tied mode.

2.1.6 Control Power

Power microprocessor-based devices integral to microgrid control from DC sources conforming to [24V][48V][125V] standard voltage levels. Devices requiring DC power encompass [controllers,][computers,][switches][, routers,][grid-connected inverters for battery storage,][generator set controllers,][inverter controllers,][firewalls,][gateways,][protection devices, meters,][and monitors].

In scenarios where AC power is lost, uninterrupted operation of communication, control, and monitoring functions is mandatory. For AC outages exceeding [_____][10 minutes][30 minutes], equipment must [enter a low-power state][or][disconnect from the DC bus] to conserve battery life for potential black start conditions.

Monitoring and alarming of DC backup batteries and associated charging circuits must be continuous on the MCS. Minimum monitored parameters must include [DC voltage][and][charger online status].

For enhanced DC bus reliability during prolonged AC outages, circuits and relays must be configured to [select AC power from a single source][select AC power from multiple sources]. In high-reliability locations, [single][redundant] DC power sources must be provided to critical electronics through [single diode arrangements][multiple diode arrangements]. During battery servicing or replacement, critical electronics must [remain connected to the DC bus][be disconnected from the DC bus] through [battery bypass circuits][chargers capable of providing DC voltage without a battery].

Engine starting batteries for generator sets may serve as [primary][backup] DC sources. Electronics must withstand a [3-second][5-second] voltage dip of [50%][40%] during engine starts.

Use of AC Uninterruptible Power Supplies (UPS) is [permitted][discouraged][not permitted].

2.1.7 Protection and Control Integration

Data pertaining to alarms, targets, health status, metering, and IEEE 2030.8compliance on the AC power system must be transmitted from protective relays to the MCS. Upon detection of a faulted, open, or erroneous circuit condition by the relays, control systems governing dispatch, voltage, frequency, power, and reactive power must cease operation in a controlled manner.

Mandatory data collection in accordance with IEEE 2030.8 data table C.1 must encompass protective relays at the point of utility coupling and all DER, including [generator sets,][inverters,][photovoltaic systems,][and Battery Energy Storage Systems (BESS).]

All required data from protective relays must be displayed on the MC HMI, including:

a. Alarms and Targets required from relays include but are not limited to: Trip, Lockout 86, ESTOP, circuit breaker bell alarm, breaker status, local/remote, permissive to close/synchronize.
b. Health status required from relays include but are not limited to: protection enable/offline status, trip status, communication status.
c. Metering required from relays include but are not limited to: 3 phase power, 3 phase reactive power, frequency on both sides of all DER and PCC breakers, phase-phase voltages on both sides of all DER and PCC breakers, current, power factor.
d. IEEE 2030.8 data required from relays to be stored for the life of the microgrid must include but are not limited to: P, Q, V, F at every DER

and PCC.

e. Required controls to the relays include but are not limited to: CB open/close, motor operated disconnect open/close, tap change raise/lower.

All required DER data from must be displayed on the MC HMI, including:

f. Alarms and Targets required from DER include but are not limited to: Trip, Lockout 86, ESTOP, circuit breaker bell alarm, breaker status (DC and AC), local/remote, permissive to close/synchronize/commutate.

g. Health status required from DER include but are not limited to: enable/offline status, major and minor alarms, communication status.

h. Metering required from DER include but are not limited to:3 phase power, 3 phase reactive power, frequency, phase-phase voltages on both sides of breakers, current, power factor, and applicable temperatures, oil pressures, levels, and fire alarm status.

i. IEEE 2030.8 data required from DER to be stored for the life of the microgrid must include but are not limited to: P,Q,V,F at every DER

j. Required controls to the DER include but are not limited to: frequency/power reference, voltage/reactive power reference, enable commutation, breaker open/close.

2.1.8 Energy Management Functions

2.1.8.1 Dispatch Requirements

All microgrid control systems are to be provided with several minimal requirements for dispatching all DER inclusive of gensets, battery inverters, PV inverters, or other energy producing DER.

The following forms of dispatch are mandatory:

a. DER offline. Each individual DER can be shut down into a mode they do not produce or consume current.
b. DER manual dispatch. Each individual DER can be started and follow a user entered setpoint set by the user at the MC HMI.
c. Grid Connected Resiliency dispatch. In this mode the system is connected to the utility and DER are dispatched to provide the best opportunity for a seamless islanding should the utility go out of service. To be used when the base is about to experience an attack or a storm.
d. Grid Connected Economic Dispatch. In this mode the system is connected to the utility and DER are dispatched to achieve the desired economic objective for the system. User objectives may include least operational cost, Demand limiting at a point of common coupling, real time price optimization, or other. Equipment health, maintenance condition, fuel prices, project investment objectives, or other are to be prioritized and met.
e. Islanded Resiliency dispatch. In this mode the system is disconnected from the utility and all reliable genset must be operated without regard for operational costs such as fuel. Intermittent energy such as PV, wind, or other must be curtailed or shutdown. Battery systems must be paralleled and commutating but only produce or consume power to assist reliable gensets. This is the most resilient and costly form of islanded dispatch used specifically during blackstarting or should the facility be under attack or in a storm.
f. [Grid Connected External dispatch. All DER setpoints are set by an

upstream 'nested' microgrid, a SCADA operations facility, or another control system. All controls of DER manual dispatch must be made available to an upstream system.]

g. [Islanded Economic Dispatch. In this mode the system is disconnected from the utility and the system is dispatched in a manner that prolongs base resources (such as fuel). Intermittent energy such as PV, wind, or other are to be curtailed as required to prevent gensets or batteries from tripping offline. This is the least costly form of islanded dispatch used specifically for prolonged utility outages.]
h. [Maintenance modes such as wet stack mitigation, monthly genset testing, or other.]

2.1.8.2 Blackstarting Requirements

Blackstarting a power system means bringing the power back only with all DER initially offline and systems de-energized. This is normally because the local utility is unavailable. The MC must provide a blackstarting system with the following minimal requirements:

a. Initiation and shutdown of the sequence must be user initiated. Auto initiation is acceptable, but optional. Blackstart sequence must automatically end and alert user of the status of success/failure of the attempt.
b. The sequence must cease should power system fault be detected.
c. The sequence must adapt to loss of monitoring or control of circuit breakers.
d. Long term (reserve margins) and short term (incremental reserve margins) of DER must be continuously abided; i.e., no loads are to be allowed to overrun the total system of DER ability to supply RM or IRM.
e. Magnetic inrush of transformers and motors must be considered prior to closing every breaker.
f. Cold load inrush associated with kinetic energy spin-up of motors and power electronic DC bus energization must be considered prior to closing every breaker.
g. Delayed load start such as building HVAC or ATS re-transfers must be considered prior to closing every breaker. Sufficient RM must be reserved should these systems come online several minutes after energization.
h. Gensets must not be damaged during starting without auxiliary AC power. DC lube oil pumps are preferred for blackstarting.
i. Engine response times must be adequate to pickup loads without excessive frequency deviations; for example lean burn natural gas gensets are much slower and smaller IRM than same sized diesels.

2.1.8.3 Restoration Requirements

Grid Restoration means bringing the power back with a healthy local utility. The MC must provide a restoration system with the following minimal requirements:

a. Initiation and shutdown of the sequence must be user selectable as manual or automatic.
b. Sequence must automatically end and alert user of the status of success/failure of the attempt.
c. The sequence must cease should power system fault be detected.
d. The sequence must adapt to loss of monitoring or control of circuit breakers.
e. Consider protection trip setpoints, cold load inrush, magnetic inrush before closing breakers.

2.1.8.4   DER Mode Selection

DER that load share without communication are strongly preferred such as GFMD and RPM control with metered power droop.

The following table shows the preferred, acceptable, and un-acceptable modes of DER primary control for the microgrid during grid connected operation.

Mode	Genset	BESS IBR	PV IBR
Preferred	RPM control with metered power droop Voltage control with metered VAR droop	Grid forming with Droop	Grid following
Acceptable	Power and VAR control with or without droop	Grid following with or without droop	
Unacceptable	Isochronous	Grid forming	

The following table shows the preferred, acceptable, and un-acceptable modes of DER primary control for the microgrid during islanded operation (no utility).

Mode	Genset	BESS IBR	PV IBR
Preferred	RPM control with metered power droop Voltage control with metered VAR droop	Grid forming with Droop	Grid following
Acceptable	Power and VAR control with or without droop	Grid forming	
Acceptable	Isochronous	Grid following with or without droop	
Unacceptable	Power and VAR control	Grid following with or without droop	

2.1.8.5   Load Shedding

The following forms of acceptable load shedding may be specified for the microgrid control system. These do not require an HIL test, but they do require a load shedding coordination study.

a. Utility requested load reduction, per an interconnect contract.

Utility commands come from SCADA either verbally or via a DNP3 communication line.

b. Utility coordinated load reduction, per an interconnect contract. Trips happen based on under-frequency thresholds and timers set in protective relays throughout the microgrid.

c. Islanded under-frequency load reductions. Trips happen based on under-frequency thresholds and timers set in protective relays throughout the microgrid. These setpoints may be either time or threshold coordinated with the utility load reductions, or they may be enabled with an islanding status from the PCC.

d. Islanded Overload load reductions. Loads are tripped when gensets and inverters approach a current or power overload.

e. Islanded Event load reduction. Loads are tripped when relays at PCC, gensets, BESS, or other detect an unexpected breaker opening. Also called contingency or fast schemes.

The following table identifies which type of load shedding are applicable for several common types of microgrids:

Type of Microgrid	Allowable Load Shedding	Comments
Utility Grid Connected	- Utility requested load reduction - Utility coordinated load reduction	Set per utility Contract
Islanded without gensets or synchronous condensor/flywheel. BESS in GFMD.	- Islanded under-frequency load reduction - Islanded Overload load reductions - Islanded Event load reduction	BESS which droop frequency on loading might allow frequency load shedding to work.
Islanded without gensets or synchronous condense r/flywheel. BESS in GFM no droop.	- Islanded Overload load reductions - Islanded Event load reduction	Frequency is not a good indication of overload on these types of microgrids.
Islanded with gensets or synchronous condenser/flywheel.	- Islanded under-frequency load reduction - Islanded Overload load reductions - Islanded Event load reduction	Kinetic energy storage allows reliable usage of more kinds of load shedding.

The following forms of load shedding require a full hardware in the loop test of the solution:

f. Under voltage based load shedding schemes.
g. Rate of change of frequency load shedding schemes.

h. Any type of load shedding not specifically called out in list of acceptable load shedding schemes.

2.1.9 Energy Reporting and Monitoring

The microgrid control system (MCS) must provide energy reporting and monitoring capabilities for effective and accurate collection and reporting for energy management and historical trending. The MCS must provide the following data at a minimum:

a. Real-time energy consumption data for all microgrid components, including generation, storage, and loads.

b. Historical energy consumption data for all microgrid components.

c. Energy production data for all microgrid generation sources.

d. Energy storage data for all microgrid storage devices.

e. Energy export/import data for the microgrid as a whole.

****

NOTE: The required points or data to be read or passed to the UMCS system must be coordinated with Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION and included in the necessary UMCS points schedules required within the construction document set. Interoperability may support aspects of microgrid design including communication with, or control of, primary assets of the Utility Control Systems (UCS) as described in UFC 3-470-01.

The corresponding input and output requirements for the microgrid control system are listed out below, or indicated in the drawing set.

Where either the UMCS or MCS requires action or procedure based on input from the other system, the internal function is required to be defined within the appropriate contract document. The MCS specification will not be used to dictate the action taken by the UMCS, and the UMCS specification will not be used to dictate the action taken by the MCS. Each will act on the signals and data received according to the internal system logic.

****

2.1.9.1 [UMCS Integration]

The microgrid control system must include hardware and software required for integration into the UMCS system. Coordinate with UMCS points schedule in the document set and Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION.

[The microgrid control system must output to the UMCS the signals and data points [indicated on the design drawings][as follows:]]

[The microgrid control system must receive as input from the UMCS the signals and data points [indicated on the design drawings][as follows:]]

2.1.10 Fault Management and Isolation

Cover how the MCS identifies, isolates, and manages faults within the microgrid and at the point of common coupling. Focused on the MCS functions, and does not duplicate the functionality of an external protection scheme or equipment. Primary function described is MCS and microgrid operation, rather than protection.

2.1.11 Data Security and Encryption

Specifically addresses how data is secured. Largely referential to the cyber security spec and heading under section 1.

2.1.12 Time Synchronization

Covers the requirement for accurate time synchronization between discrete components, DER controllers, and the MCS. Describe the protocols and accuracy levels required using industry standard references.

2.1.13 Communication Standards

2.1.14 Failover and Redundancy

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NOTE:Using UFC 3-550-04 as a reference, consider the requirements for controller or controller component failover, network redundancy, and backup power for the microgrid control system (separate from the microgrid itself).

Microgrid specifier is to call out which types of redundancy are allowed. The following list is sorted in order of value; i.e., least cost/best performance.

****

[a. Local/Remote. Each DER, PCC, and circuit breaker to have both a remote microgrid control system, and local controls including Human machine interface visualization, DER dispatch, breaker open/close.

][b. Network. RSTP or SDN must be configured to provide continuous communication between DERs and the MC in the case of a communication cable breakage or switch/router outage.

][c. Dual Primary MC. In this method two MC must be provided with duplicate code that is running real time and racing to make a decision such as load shedding.

][d. Hot Standby MC. In this method two MC must be provided with duplicate code; one is running and the other is powered up but disabled.

][e. Cold Standby. Spare parts that are wired but not powered up provide redundancy.

]2.1.15 Data Storage

Capture the following IEEE 2030.8 data for the life of the microgrid for future root cause analysis.

Table 2.1: IEEE 2030.8-2018 Table C.1, Minimum data collection

Type of data collection	Minimum time synchronized accuracy	Minimum sample rate	Minimum amplitude accuracy	Required data to collect	Required to meet IEEE 2030.7
Sequence of events (SOE) records	One quarter power system cycle (0.004166 s for a 60 Hz system)	One quarter power system cycle.	N/A	Digital data only. Examples are: Switching device (breaker, recloser, and switch) open and close status, commands, protection elements, control outputs and interlocks	Yes
Event oscillography (OSC)	One quarter power system cycle	One quarter power system cycle	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes
Continuous data collection (CDC)	One quarter power system cycle	100 ms	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes

All microgrids must provide field data collection at Level 3, per the IEEE standard section C.2 repeated below.

Level 1 - Data must be collected at and on both sides the POI for any microgrid with one DER.

Level 2 - Data must be collected at every DER and POI for any microgrid with two or more DER.

Level 3 - Data must also be collected at the load(s) and the DER for any load greater than 50% of the largest DER and for any single load larger than 10% of the maximum total power consumed by the microgrid.

2.1.16 Utility Interconnect

2.1.16.1 Utility Interconnection Agreement

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NOTE: Typically, the designer should begin the utility interconnection agreement, and this specification assumes that process has been . As such, specifications should be crafted to account for and address the complexities that arise from these arrangements, ensuring clear delineation of responsibilities and requirements for all parties involved, including the contractor and utility providers.

****

Submit for record, a finalized utility interconnection agreement required to have the following attributes:

A signed legal Contract which defines the parameters and requirements for the following minimum items:

a. Energy Rates (kWh) for both import and export

b. Power demand charges (kW)

c. Any other recurring charges

d. Reverse power (32) limitations

e. Frequency ride-through requirements (Hz and time in seconds or milliseconds)

f. Voltage ride-through requirements (Volts and time in seconds or milliseconds)

g. Equipment ownership delineation, including who is responsible for settings and testing every electronic device as the interconnect.

h. Linkages to the engineering protection requirements (standards), including but not limited to overcurrent elements, directional elements, distance, direct transfer trips, lockouts, anti-islanding, or other related protection requirements.

i. Deadbus arbitration requirements including all synchronization requirements.

j. Any regulatory requirements enforced by local, regional, state, or federal entities such as the EPA, NERC, or other.

k. Data recording requirements including fault recording, SOE recording, synchrophasor collection, or other.

l. Any required sequence of operations, such as paralleling or isolation from a utility owned asset.

m. Description of premises access such as behind locked gates or doors Cyber requirements including but not limited to applicable standards and all required documentation.

n. Identify any engineering processes, checklists, or reviews that must be completed.

o. Lowest and highest symmetrical and asymmetrical fault currents the utility can provide.

p. Utility Thevenin equivalence during normal operation.

q. Utility changes to their infrastructure which case the steady state Thevenin equivalent of the utility (impedance) or fault currents to change more than 5% must be shared with base 6 months in advance.

2.1.16.2 Protection System Interface & Coordination

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NOTE: Designer is required to coordinate the MCS with the protection system. Recommendations for protection system operation with relation to the MCS and microgrid can be found in UFC 3-550-04. Supplemental recommendations below:

MCS is required to have the ability to isolate from the grid without utility permission; i.e., at least one circuit breaker is required to be under the microgrid control systems purview in addition to any utility-controlled PCC equipment.

Breaker status, close premissive, warning, trips, and targets are required to be identified on the MPCC relay, and not on the MCS.

****

a. Reverse power (32) elements are required to be coordinated with the slowest on-site DER.

b. Reverse directional fault detection (67) elements are required to be disabled should there be insufficient conventional synchronous generators or condensers in the microgrid.

c. Should 67 be viable, faults detected on the microgrid side are required to be isolated and require the microgrid blackstart and islanding features to be disabled.

d. Should 67 be viable, faults on the utility side must not inhibit microgrid islanding or blackstart.

e. All utility side neutral ground bonding is required to be identified to the MCS and incorporated into the HMI.

f. All CB open and close commands are required to be routed through the associated microprocessor relay; i.e., no direct close or open commands are allowed to be wired to the CB from the MCS.

g. All load shedding associated with the PCC opening is required to be capable of being inhibited (shut down) at the PCC protection relay.

h. Status of a synchronization attempt including a synchroscope, in operation, and failed status is required to be annunciated at the PCC relay.

i. All deadbus and synchronization logic is to reside in the PCC relay and not within the MCS.

j. Auto reconnection (re-transfer) functions of the PCC to the utility is required to be available and can be turned off/on at the PCC relay.

k. All remote commands including close and open from the MCS are required to be disabled by a local/remote pushbutton or switch at the PCC relay.

l. Live and deadbus indication must be annunciated on the PCC relay and to the MCS.

2.2 MICROGRID CONTROL SYSTEM COMPONENT DEVICE REQUIREMENTS

The following is a minimum set of criteria required for all microprocessor (intelligent) devices used on the microgrid:

a. Spares either readily available for purchase or purchased and placed in storage, and may be powered up to maintain equipment health.

b. All configurations/ settings/code on every device must be stored in a single engineering workstation or server.

c. All processes of setting up spares or replacement parts must be documented and the process must be tested.

d. All configurations/ settings/code must be tested to be easily uploaded/downloaded to spares and placed into service with no ill effect.

e. No annual licenses, software licenses, configuration licenses, data access licenses are allowed. Electronic equipment and their configurations must be purchased in perpetuity without further fees. A single use license on software/ hardware/algorithms is acceptable to preserve supplier intellectual property however no fees past initial purchase are allowed.

f. Supplier must supply cyber and functionality based service bulletins alerting the owners of potential vulnerabilities and or defects in the product.

g. Defects in software/configurations must be warranted for a minimum of 1 year.

h. Hardware/firmware must be warranted for a minimum of 10 years.

i. All electronics must operate in conditions -30 to +75 Celsius.

j. Intelligent and Secure Components. All electronic equipment must continuously self-test and report internal errors.

k. Devices taking part in microgrid control must include an integrated IEC 61131-3 programming environment.

l. Devices taking part in microgrid protection must include some form of free form logic programmability.

m. Devices must incorporate independent user-based security with strong passwords.

n. All devices must provide a mechanism to map security related system tags into a report or communicated data stream for the user to monitor.

o. All devices must support some form of human-machine interface or LED annunciation which allows the user to determine the health of the equipment.

p. All devices must support some form of time synchronization which keeps all CPU clocks within 8 milliseconds throughout the microgrid.

q. There must be an alarm contact output to signal internal errors and malfunctions.

r. Control, communication, and networking equipment must meet IEEE 1613:2003.

s. Protective devices must meet IEC 60255-21-1, IEC 60255-21-2, IEC 60255-21-3, IEC 60255-26, IEC 61000-4-4, and IEEE C37.90.1.

t. Utilize non-volatile memory available for user programmable retained variables.

u. Engineering Access must be available [over secured network][or][and][locally by direct connection].

v. All electronic boards must be conformal coated.

w. Minimum mean time between failure (MTBF) of 200 years.

2.2.1 Product Certifications

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NOTE: FCC part 15 does not apply to many of the computing devices used for industrial applications. Title 47 Part 15 provides for exemption of unintentional radiators considered "digital devices used exclusively as an electronic control" or power system utilized by a public utility or in and industrial plant.

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All electronic product certifications must be provided on product data sheets. Conformance is required the following minimum requirements:

a. Designed and manufactured by an ISO 9001 US based certified manufacturer

b. UL Listed to U.S. and Canadian safety standards
c. Time synchronization to better than 4 ms
d. MTBF minimum of 300 years.
e. Meet or exceed IEEE 1613
f. IEEE 1613 + A1-2011 Service Conditions IEC 60068-2-1, -40°C, 16 hours
g. IEEE 1613 + A1-2011 Service Conditions IEC 60068-2-2, 85°C, 16 hour
h. IEC 60068-2-30 25°-55°C, 6 cycles, 95% relative humidity, or equivalent.
i. Section IEEE C37.90.1, Impulse Section Severity Level: 0.5 J, 5 kV, or equivalent.
j. Electrostatic Discharge Immunity: IEEE 1613 + A1-2011 IEEE 1613 ESD, or equivalent.
k. Magnetic Field Immunity: IEC 61000-4-8 1000 A/m for 3 seconds, 100 A/m for 1 minute, or equivalent.
l. Power Supply Immunity
m. Radiated RF Immunity: IEEE C37.90.2, 35 V/m, or equivalent.
n. Digital Radio Telephone RF Immunity: ENV 50204:1995 10 V/m at 900 MHz and 1.89 GHz, or equivalent.
o. Minimum protocols of the MC controllers and gateways must be: [Modbus RTU,][Modbus TCP,][DNP/IP,][DNP/RTU,][Modbus,][MIL-STD-3071,][NTP,][LDAP].

2.2.2 Product Sourcing

All intelligent electronic devices must be sourced exclusively from the US. This includes board production, board population, firmware creation, code storage, firmware download, microprocessor production, and final assembly. See the Quality Control section for further traceability requirements of sub-assemblies. Non intelligent devices need only meet the traceability requirements.

2.2.3 General Requirements

NERC/CIP user authentication, logging, and port control requirements.

Mean time between failures of minimum 10 years per device. MTTF must be measured not calculated based upon customer product returns.

All status and control traffic between MC, DERS, POI, PCC and load devices able to be shed must be MIL-STD-3071 compliant. Remainder of system must be integrated via other protocols to protective devices, genset controllers, tap changer controllers, intelligent circuit breakers, UMCS, SCADA, and other devices as required.

2.2.4 Nameplates and Identification

All electronic devices must have nameplate indicating part number, serial number, and product manufacturer and country of origin. Per the ITP, all products must be traceable via their serial number.

2.2.5 Warning Labels

Product instruction manual must alert users of dangerous conditions. Labels must be installed in panels, on door, etc. as required for all location with human contact with said dangerous conditions.

2.2.6 Product Data Sheets

Product data sheets must be available on the supplier's corporate website.

2.2.7 Firmware and Software Updates

2.2.8 Environmental Ratings

(detail the environmental ratings requirements for the MCS equipment; IP ratings, NEMA enclosure rating requirements, etc. based on installed location and whether the space is normally conditioned, or conditioned by equipment powered by the microgrid in islanded operation)

2.3 CONTROL HARDWARE

All Facility Related Controls Systems (FRCS), which includes the SCADA System, must meet current Control Systems Platform Enclave/Navy Utilities Monitoring Control Systems (CSPE/NUMCS) Authority to Operate (ATO) requirements.

2.3.1 General Requirements

The Microgrid Control System (MCS) must be connected to electrical equipment for control, monitoring, and data gathering as part of the microgrid control system. The MCS must be micro-processor based, capable of receiving discrete and analog inputs, and, through programming, must be able to control discrete and analog output functions, perform data handling operations and communicate with external devices.

2.3.2 MCS Modules

Provide MCS modules that are field expandable design allowing the system to be tailored to the control application. The system must be expandable through the use of additional hardware and/or user software. As a minimum, the MCS must include a power supply module, central processing unit (CPU) module, communications module, and input/output (I/O) module, including discrete I/O modules. The MCS must include non-volatile memory to be saved on a loss of power.

The MCS must be a self-contained, microprocessor-based unit that provides time of day, scanning, application program execution, PID control with manual and self-tuning capabilities, custom function blocks, storage of application programs, storage of numerical values related to the application process and logic, I/O bus traffic control, peripheral and external device communications and self-diagnostics. Programming must be IEC-61131 compliant. The control firmware must whitelist all applications and have self-diagnostic checks.

Communications must allow peer-to-peer communication with other relays and controllers and must allow the MCS to communicate with any existing control system equipment, or workstation computer. Communication modules must support [serial and Ethernet][Ethernet] architecture and protocols. Programming of the MCS to be done locally or remotely with software that meets minimal NERC/CIPs requirements.

2.3.3 Power Supply Module

One or more power supply modules must be provided as necessary to power other modules installed in the same cabinet. Auxiliary power supplies may be used to supply power to remote cabinets or modules . Power supplies must produce either DC or AC as required or the MCS and other ancillary electronics. Power supplies can be either external or internal to the MCS.

a. The power supply module must monitor the DC or AC supply and alarm if the voltage falls out of spec. The MCS must have sufficient ride through to sustain 10 minutes of AC outage. This can be done with batteries or capacitive energy storage. Direct DC battery connected solutions are preferred as UPS solutions are a costly maintenance item. b. Every device must be capable of being powered off with a fuse, circuit breaker, or switch.
c. All electronic devices must annunciate the health of their status on front mounted, easily viewable LEDs.
d. Health of all DC or AC UPS buses is to be annunciated to the MCS HMI, including voltage level.

2.3.4 MCS Program Storage/Memory Requirements

The MCS must utilize nonvolatile memory for the operating system. The controller must have both nonvolatile and volatile memory that can be programmed. The memory capacity must be sized such that, when the system is completely programmed and functional, no more than 20 percent of the memory is used for real time processing of logic. No more than 50 total percent of the memory may be used, inclusive of all operating systems, code, protocols, data archiving, etc. CPU total processor burden must not be above 50% during normal operation.

2.3.5 MCS Input/Output Characteristics

Provide analog input, analog output, discrete input and discrete output. These can be either wired to the local or remote IO modules and or relays. The number and type of inputs and outputs for the system must be as shown on the drawings and must comply with the sequence of control. The system capacity must include a minimum of 20 percent spare input and output points (no less than two points) for each point type provided.

2.3.6 MCS Wiring Connections

Wiring terminals within the MCS to central controllers, distributed controllers, relays, and IO modules must be [in accordance with Section 40 60 00 PROCESS CONTROL][as follows:

a. All CT connections must accept 12 AWG with crimped ring terminal terminations.
b. All PT connections must accept 14 AWG with crimped ring terminal or compression terminations.
c. Digital outputs inclusive of dry contacts, sourcing, or sinking type must accept two 16 AWG with crimped ring terminal or compression terminations.
d. Digital inputs sourcing or sinking type must accept two 16 AWG with crimped ring terminal or compression terminations.
e. Analog inputs and outputs must accept two 16 AWG with crimped ring terminal or compression terminations.]

2.3.7 MCS Diagnostics

Implement diagnostic routines in firmware. The MCS must continuously perform self-diagnostic routines that provide information on the configuration and status of the MCS, memory, communications and input/output. The diagnostic routines must be regularly performed during normal system operation. All faults must be annunciated at the MCS/HMI and any existing control system head end.

All serial and Ethernet communication channels must have LED annunciating the Transmit and Receive hardware line status of their respective port.

2.3.8 Interface with DER

The microgrid control system must be capable of integrating with various DER, such as solar photovoltaic systems, wind turbines, energy storage systems, and gensets . It must enable real-time monitoring and control through bi-directional communication with DER devices.

To optimize DER management, the microgrid control system must include features such as load shedding, demand response, curtailment, and peak shaving. Dispatch algorithms must autonomously adjust DER output and/or load based on equipment health, grid topology, DER health, DER fuel levels, DER capability curves, load conditions, grid conditions, demand patterns, and [optionally weather forecasts].

The controller and/or a Historian must collect data from all DER, PCC, and load devices per IEEE 2030.8 standards Table C.1 repeated below. Historical data may be used to evaluate performance and enhance energy optimization. The historian must use open industry-standard communication time-stamped protocols such as MIL-STD-3071,IEEE 37.118, IEC-61850 GSSE, DNP, or other. Non time stamped data must not be allowed in a historian nor allowed to be used in a microgrid optimization algorithm.

Table 2.2: IEEE 2030.8 Table C.1, Minimum data collection

Type of data collection	Minimum time synchronized accuracy	Minimum sample rate	Minimum amplitude accuracy	Required data to collect	Required to meet IEEE 2030.7
Sequence of events (SOE) records	One quarter power system cycle (0.004166 s for a 60 Hz system)	One quarter power system cycle.	N/A	Digital data only. Examples are: Switching device (breaker, recloser, and switch) open and close status, commands, protection elements, control outputs and interlocks	Yes

Type of data collection	Minimum time synchronized accuracy	Minimum sample rate	Minimum amplitude accuracy	Required data to collect	Required to meet IEEE 2030.7
Event oscillography (OSC)	One quarter power system cycle	One quarter power system cycle	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes
Continuous data collection (CDC)	One quarter power system cycle	100 ms	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes

2.3.9 Protocols

The microgrid control system must support industry-standard communication protocols to ensure efficient data exchange and integration with connected devices. Microgrid proven protocols include the following:

2.3.9.1 Modbus (Modicon Communication Protocol)

This protocol is very commonly used for communication with compatible devices such as inverters, genset controllers, gateways, relays, I/O modules, meters, and battery management systems. Modbus is widely used in the industry for monitoring and controlling distributed assets.

2.3.9.2 MIL-STD-3071

This standard describes a structured Data Distribution Service (DDS) data model adequate for all scales of microgrids. This standard also includes control system and data sets build specifically for microgrids, with designs for real time and non-realtime and high and low priority data sets. This allows the microgrid to interoperate/communicated with tactical/portable equipment such as tanks, trucks, and emergency portable gensets for rapid microgrid deployments.

2.3.9.3 IEC 61850

This standard includes a real time GOOSE and non-realtime MMS protocol. IEC 61850 GOOSE is designed for sub-millisecond level control and monitoring between controllers. MMS is a non real time protocol used for SCADA annunciation.

2.3.9.4 DNP 3.0

This is the north American de-facto standard for intercommunication with all electric utilities and SCADA systems.

2.3.9.5 ANSI C37.118

This is the North American de-facto standard for power system historians. Data is time stamped at the lowest level and re-aligned for historians and controllers.

2.3.9.6 Coordination

Coordinate and confirm that the microgrid control system fully supports the applicable communication protocols allowing for smooth interoperability and efficient operation with a wide range of devices and systems within the microgrid network. The implementation of these protocols must be thoroughly tested and validated during commissioning to guarantee reliable and secure data exchange throughout the system.

2.3.10 Data Concentrators

The microgrid control system must include data concentrators to efficiently aggregate data from connected devices and sensors within the microgrid. These concentrators must minimize network traffic and ensure smooth communication throughout the system.

The data concentrators must act as gateways, enabling bidirectional communication with various devices and sensors across the microgrid. They must support different data formats and industry-standard protocols to promote interoperability.

The microgrid control system's data concentrators must possess advanced data processing capabilities, facilitating real-time analysis and filtering. This optimization is to ensure streamlined data flow to the controller, reducing latency and enhancing overall system responsiveness.

Emphasizing reliability and security, the data concentrators must implement robust cybersecurity measures to protect data integrity and confidentiality.

The microgrid control system must support scalable data concentrators, allowing for integration of new devices and system expansions. Thorough testing and verification of functionality must be conducted to ensure successful integration within the microgrid.

2.3.11 Gateways

Gateways (also known as front end processors) must be provided to allow monitoring data to be interfaced directly with lower tier LANS and their electronics. Gateways must be provided with sufficient quantity of RS-232, RS-485 serial , and RJ45 Ethernet ports to accomplish the mission. Gateways can be configured as uni- or bi-directional protocol translators and must be configurable from a central engineering workstation(s). The gateways must operate from the same power sources described for the MCS.

The microgrid control system may incorporate gateways to facilitate efficient data transmission among microgrid components, DER devices, and the central monitoring system (SCADA). These gateways must support both real time and non real time data.

Gateways must be capable of supporting various communication protocols and networking technologies, promoting seamless integration with different devices and systems within the microgrid.

Emphasizing cybersecurity, the gateways must implement robust encryption and authentication mechanisms to safeguard data during transmission.

The microgrid control system's gateways must be designed for scalability, accommodating future expansions and new DER devices without compromising performance.

Comprehensive testing and validation of the gateway functionality must be conducted to verify its operation within the microgrid.

2.3.12 Ethernet Switches

2.3.12.1 Product Description

The microgrid control system may utilize Ethernet switches, capable of configuration and monitoring, to support a reliable and resilient communication network. Network switches must provide communication between network devices using 10/100/1000 MB Traffic over Copper and Fiber optic media. All network switches must support [software defined networks (SDN)][rapid spanning tree protocol (RSTP)]. Network switches must permit online network changes without disturbing network devices. Malfunctioning network devices must be automatically removed from service without shutting down the network.

2.3.12.2 Environmental Requirements

The switches must operate within a temperature range of -40°C to 85°C without the need for fans, ensuring reliability in harsh environments.

2.3.12.3 Power Supply

The switches must be equipped with integrated [optional - redundant] and high mean time between failure (MTBF) power supplies to ensure continuous operation and avoid single points of failure.

2.3.12.4 Encryption

The switches must implement industry-standard SSH/SSL encryption with a minimum key length of 128-bit to safeguard data transmission and protect against unauthorized access.

2.3.12.5 Passwords

The switches must support multi-level passwords to enable role-based access control, ensuring authorized personnel can access and configure the switches while maintaining security. These passwords must be provided to the government for record and on-going operation.

2.3.12.6 Port Security

Managed switches utilizing RSTP must implement MAC-based port security and support network access control 802.1x to enhance the overall network security. SDN switches natively provide port security through deny by default configuration.

2.3.12.7   Traffic Shaping

This must isolate high and low priority/latency traffic, and to prevent unnecessary traffic burden and fast system reconfiguration during failures. RSTP switches must utilize VLANs and RTSP to shape traffic. SDN switches natively shape and prioritize traffic.

2.3.12.8   Ports

The switches must include various types of ports, including but not limited to single mode gigabit 1000LX SFP uplink ports, 100BASE-FX multimode fiber ports, and copper RJ45 Ethernet ports, ensuring compatibility with different connected devices. Network switches may include, but are not limited to the following physical characteristics:

10/100/1000 Base-T ports
1000 Base-LX ports
1000 Base-LX and 100 Base-FX downlink ports
Support the protocol utilized in the microgrid control system
Small form factor pluggable (SFP) downlink ports optional
Rack/panel or backplane mounted options
LED indicators for each port for network monitoring status
Twenty percent spare ports must be provided for all network switches

2.3.13   Network Design

Networks designed to facilitate the communication requirements for Microgrid Control Systems must be coordinated with local installation telecommunication providers to determine both outside telecommunication plant dependencies and local cybersecurity interconnection requirements. Cybersecurity design requirements for Microgrid Control Systems should refer to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS. The following list are suggested designs to help the user achieve ATO, but it is by no means a complete or definitive list.

2.3.13.1   Firewalls

Firewalls must be placed between OT/IT interfaces, or at jurisdictional interfaces such as at UMCS or Utility SCADA systems. Dual firewalls and/or gateways at critical interfaces are acceptable.

2.3.13.2   Remote Engineering Access

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NOTE: Remote engineering access is typically forbidden. Confirm prohibition or allowance with Government prior to selection in this specification section.
****

[Remote Engineering Access is prohibited. Equipment with hardware allowing remote engineering access is prohibited. Disabling via software only is not acceptable.]

[Upon written permission from the Government remote engineering acess may be enabled. At all times when engaged, qualified staff must be in attendance at all times this remote access is powered on. Remote access must be powered off and air gapped if not under immediate supervision of qualified staff.]

2.3.13.3 Remote Control and Monitoring Access

Provide means for temporary facilities control system, utility SCADA, or building management system to remotely monitor and control the MCS. The remote control inteface must include a manually activated cut-out switch preventing remote control and allowing for lock out and tag out of the remote control interface. Allow for remote control of setpoints such as demand limit, demand response signals, or periodic maintenance functions; monitoring points such as energy, power, power factor, and voltage flow for the microgrid and each connected and controlled DER or load. For this interface, firewalls and protocol gateways are to be used to build a DMZ. Only approved protocols may pass through this DMZ; see prior list of approved MCS protocols.

2.3.13.4 Remote Internet Access

Internet connections are forbidden on all DoD microgrids.

If a project must have a remote Internet access for a forecasting algorithm, then a strict usage of a transmit-only serial channel imitating a traditional UART data diode is required.

2.3.13.5 On-site LAN

The microgrid controller must support on-site Local Area Network (LAN) gateway functionality to facilitate communication within the microgrid and local devices.

[2.3.13.6 Dedicated ADSL

Where external network communciation is required and has been permitted by the Government in writing, the microgrid controller may include a dedicated Asymmetric Digital Subscriber Line (ADSL) gateway to enable secure communication with external networks, such as remote monitoring and control systems. This must abide by the Remote Control and Monitoring practices outlined above.

]2.3.14 Supervisory Dispatch Controllers

The microgrid control system may incorporate advanced supervisory dispatch algorithms to efficiently oversee and coordinate the seamless operation of all local and remote microgrid components and DER devices. These algorithms may perform a number of functions, including but not limited to: optimize power flow within the microgrid, ensuring optimal performance, meeting a return on investment, optimizing grid stability/resiliency, or other. These supervisory dispatch algorithms may be centralized or distributed controls.

Leveraging real-time data, the supervisory algorithms may dynamically adjust and optimize the microgrid's electrical power generation, energy storage, load curtailments, and consumption patterns based on load demand, fuel prices, fore-casts, present weather conditions, equipment health, maintenance cycles, and more.

2.3.15 Human Machine Interface (HMI)

The microgrid control system must provide a user-friendly Human-Machine

Interface (HMI) for efficient interaction with the microgrid control system. Design and implement HMIs in accordance with ISA 101.01, "Human Machine Interfaces for Process Automation Systems." Ensure that all aspects of HMI design, including layout, user interaction, information display, and system feedback, comply with the best practices and guidelines established in this standard. Submit Microgrid Control System HMI graphical mockup prior to or alongside related microgrid control system product data submittals.

2.3.15.1 HMI Layout and Organization

Organize HMI interfaces to emphasize clarity, ease of use, and effective communication. Organize interface layouts intuitively to facilitate quick understanding and efficient operation, following ISA-101.01 guidelines for hierarchical display structuring.

Identify control areas within the microgrid where operators have direct influence. Use intuitive, accessible color schemes and labeling for quick recognition.

Provide Level 1 display as defined by ISA 101.01 indicating operator's realm of control and microgrid status. Control may not be performed from the Level 1 display. Ensure only one Level 1 display is available for each operational state, with contextual links to appropriate Level 2, 3, and 4 displays. The Level 1 display must provide quick and easy access to additional information, leading to Level 2 displays.

Show current microgrid operational state, major equipment status (e.g. connected or offline for DERs, and open/closed for controlled breakers and switches), and highlights anything which requires immediate attention such as a high priority alarm, SOC failure status, or indications of abnormal status.

Include a high-level one-line diagram of the microgrid, including generation sources, storage, and load centers, focusing on clarity and ease of interpretation. Display real-time status indicators for critical components, including power generation units (solar panels, wind turbines, generators), storage systems (batteries), and main switches. Indicators must reflect operational status (on/off), fault conditions, and maintenance alerts.

Include a dynamic energy flow diagram showing the direction of power flow between generation, storage, loads, and the main grid. This diagram helps in understanding the current operational mode of the microgrid (islanded, grid-tied, charging, or discharging).

Integrate a section for system alerts and alarms, highlighting any abnormal conditions or operational issues that require immediate attention.

Include intuitive navigation options to detailed screens for in-depth monitoring and control of specific microgrid components.

Develop multiple Level 2 displays for the microgrid control system as defined by ISA 101.01. These displays are the primary interfaces for operator interaction, designed to align with operators’ mental models of the microgrid and its operations. Level 2 displays illustrate detailed insights and controls for specific operational states, such as startup, normal operation, transitions, and shutdown.

Integrate essential performance metrics related to the microgrid's operational efficiency, such as energy generation, consumption, storage levels, and grid interaction.

Provide direct controls necessary for managing the microgrid, including interfaces for adjusting generation sources, storage, and load management. Where space is limited, provide easy access to Level 3 and 4 displays, control panels, and detailed control interfaces.

Display relevant alarms for the microgrid's operational state, prioritizing them based on severity and relevance to the current display. Ensure visibility of high-priority alarms and indicate the presence of additional alarms.

Provide a direct link to the Level 1 overview display, enabling operators to quickly shift to a macro-perspective of the microgrid's status. Highlight abnormal conditions in the microgrid or Level 2 sub-system displayed, clearly indicating their severity and the related options for operator action.

For each parameter or datum displayed, provide links to the data historian for real time and historical trends of critical parameters such as state of charge, power, reactive power, frequency, and voltage as all defined by IEEE 2030.8 Table C.1 continuous data collection.

Include links to other applications or natively display the IEEE 2030.8 Table C.1 SOE and oscillography data.

Group related components logically for easy navigation and comprehension.

Displayed Information must indicate the quality of service; i.e., indicate if the tag is stale or the communication source is offline.

Real-Time Data Visualization:

a. Utilize graphical representations including but not limited to charts, historical and real-time trends, dials, X-Y plots, polar plots, or similar graphs to visualize data, facilitating operators' ability to make informed decisions rapidly.

b. Implement color-coding and visual cues to signify different states of microgrid components and alarms, effectively drawing attention to critical conditions. All color coding to be shaded and annotated sufficiently to allow color blind personnel to effectively use the HMI.

2.3.15.2 Alarm and Event Management

****

NOTE: As the connected equipment sizes, types, locations, and available alarm parameters will vary greatly between designs, the designer must review and supplement the alarm points listed below to suit the details of the microgrid and MCS under design.

****

Incorporate into the HMI a clear and distinguishable alarm system that provides audible and/or visual alerts for abnormal microgrid conditions and events. Display alarm details, such as severity, equipment, location, and timestamp, to help operators identify the cause and prioritize responses effectively. Use intelligent alarming techniques in accordance with ISA 18.2, Management of Alarm Systems for the Process Industries.

Timestamping must be in accordance with IEEE 2030.8 Table C1.

Alarm Acknowledgment and Management: The HMI must allow operators to acknowledge and manage alarms, providing options to silence audible alarms, acknowledge issues, and review historical alarms. Time stamped SOE data in accordance with IEEE 2030.8 are preferred for alarming.HMI include discrete display and logging of high priority alarms for each connected equipment and device. Specific requirements include but not are not limited to:

[a. PCC/POI Alarms: [_____]
 (1) Power quality out of range Harmonics, Flicker
 (2) Grid synchronization failure
 (3) Frequency out of range
 [(4) Voltage out of range]
 [(5)_____]]

[b. Connected DER Alarms: [_____]
 [(1) Inverter fault]
 [(2) Communications failure]
 [(3) Battery storage critical reserve level]
 [(4) Start/run failure]
 [(5) Generator Fuel Critical level]
 [(6) Generator Fuel system leak or malfunction]
 [(7) Generator high temperature]]

[c. Sequence of Operation Failure Alarms:
 [(1) Islanding failure]
 [(2) Load shed failure]
 [(3) Load restoration failure]
 [(4) Breaker or Switch operational failure]
 [(5) Communication loss for DERMS]
 [(6) Sequence deviation]]

[d. General Condition Alarms:
 (1) Bus under and over-voltage
 (2) Production shortfall; automatic load shed
 (3) Bus phase imbalance
 (4) Internal microgrid fault
 (5) Protective relay system tripping
 (6) Emergency stop engaged; manual or automatic
 (7) Communications fault
 (8) Communications system fallback engaged
 [(9)_____]]

[e. Additional Alarms: [_____]
 [(1) Remote access to MCS initialized]
 [(2) Fire alarm system, alarm condition reported]
 [(3) Connected equipment trouble or maintenance alerts]
 [(4)_____]]

Control and Setpoint Adjustment:

f. Equip Level 3 displays with intuitive for adjusting setpoints, operational modes, and control strategies, based on changing load conditions and the availability of DER.

g. Implement password-protected access for sensitive control functions to ensure only authorized personnel can make critical changes.

Data Logging and Historical Trending: Include data logging and historical trend visualization features in the HMI, enabling operators to analyze past performance, identify patterns, and optimize microgrid operations over time.

User Help and Support:

h. The HMI must include context-sensitive help and guidance to assist operators in utilizing its features effectively and understanding specific functions at each screen.
Provide documentation links or tooltips for complex features to enhance usability.

Responsiveness and Compatibility: Design the HMI to be responsive and compatible with various devices, including desktops and tablets to facilitate remote monitoring and control.

Local and Remote: Local controllers/relays may have HMI with subsets of the primary HMI, thus providing a cyber-secure backup system.

Multiple instances of the Microgrid Control System HMI may be provided for geographic convenience.

2.3.16 Workstation Hardware (Desktop and Laptop)

****

NOTE: Coordinate with the project site to determine if the workstation(s) will be contractor supplied or Government Furnished, or a mix where some workstations are Government furnished and others are contractor supplied: "Replace Brackets" instructions 1) Government furnished only : Keep first bracketed text and remove the [as indicated]. 2) Contractor supplied only: Keep the second bracketed text. 3) Combination of Government furnished and Contractor supplied: Keep all bracketed text. When keeping bracketed text (Contractor supplied or combination of Government and Contactor supplied) note that computer technology changes quickly and these requirements should be edited to reflect current products. Default requirements (current as of 2012) have been provided in brackets.

****

[The Government will provide the][Provide a standard desktop computer or a laptop meeting the following minimum requirements for the] Computer Workstation Hardware (workstation) [as indicated].

2.3.16.1 Processor

2.3.16.1.1 Desktop

Quad-core processor designed for desktop applications. Processor speed must be at least 75 percent of the speed of the fastest Intel desktop processor commercially available.

2.3.16.1.2 Laptop

Quad-core processor designed for laptop applications. Processor speed must be at least 50 percent of the speed of the fastest Intel laptop processor commercially available.

2.3.16.2   Random Access Memory (RAM)

[____][300 percent of the recommended requirements of the software to be installed on the server[and no less than 8GB].]

2.3.16.3   Communications Ports

2.3.16.3.1   Desktop

[____][Six USB ports.]

2.3.16.3.2   Laptop

[____][Two USB ports, plus a PCMCIA card slot or an additional USB port, plus an integral RS-232 serial port or an additional USB port and a USB to RS-232 serial adapter.]

2.3.16.4   Hard Drive and Controller

[2.3.16.4.1   Desktop

[____][1.5TB] or larger with a SATA-3 controller.

][2.3.16.4.2   Laptop

[____][250GB] or larger solid state drive.

]2.3.16.5   Optical Drive

[____][DVD-RW drive]

2.3.16.6   Video Output

2.3.16.6.1   Desktop

[____][32-bit color with dual monitor support minimum resolutions of 1920 by 1080 at minimum refresh rates of 70 Hz and dual DVI or display port outputs.]

2.3.16.6.2   Laptop

[____][32-bit color with a minimum resolution of 1920 by 1080 at minimum refresh rates of 70 Hz and VGA or HDMI output.]

2.3.16.7   Network Interface

2.3.16.7.1   Desktop

[____][Integrated 1000Base-T Ethernet with RJ45 connector.]

2.3.16.7.2   Laptop

[____][Integrated 1000Base-T Ethernet with RJ45 connector and an integrated IEEE 802.11b/g/n wireless interface. The Laptop must have a physical switch for activation and deactivation of the wireless interface.]

2.3.16.8   Monitor

2.3.16.8.1   Desktop

[____][Dual widescreen flat panel LCD monitors sized as indicated but no less than600 mm 24 inch nominal with minimum resolutions of 1920 by 1080 pixels and a minimum refresh rate of 70Hz.]

2.3.16.8.2   Laptop

[____][LCD Screen sized as indicated but no less than 325 mm 13 inch nominal with a maximum supported resolution of no less than 1600 by 900 pixels.]

2.3.16.9   Keyboard and Smart Card Reader

2.3.16.9.1   Desktop

[____][101 key wired USB keyboard having a minimum 64 character standard ASCII character set based on ANSI INCITS 154 and an integral smart card reader compatible with a Department of Defense Common Access Card (CAC).]

2.3.16.9.2   Laptop

[____][Standard laptop keyboard. Internal smart card reader compatible with a Department of Defense Common Access Card (CAC).]

2.3.16.10   Mouse

2.3.16.10.1   Desktop

[____][2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.]

2.3.16.10.2   Laptop

[____][Integrated touch-pad plus a 2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.]

2.3.16.11   Printers

Provide local or network printers as indicated. Provide local printers which have a USB interface. Provide network printers which have a 100Base-T or faster interface with an RJ45 connection and a firmware print spooler compatible with the Operating System print spooler.

2.3.16.11.1   Alarm Printer

Provide alarm printers which use sprocket-fed fanfold paper with adjustable sprockets for paper width up to 280 mm 11 inches. Alarm printers must have programmable control of top-of-form. [Provide floor stands with paper racks for alarm printers.]

2.3.16.12   Operating System (OS)

****

NOTE: Coordinate with the project site to determine if the OS license will be contractor supplied or Government Furnished.

****

****
NOTE: This subpart uses tailoring options to indicate the Gold Master version to use.
****

Provide the latest version of the Army [DISA][____] Gold Master Windows Operating System. The Operating System media will be furnished by the Government. [Provide][The Government will provide] the Operating System license.

2.3.16.13 Virus Protection Software

****
NOTE: Coordinate with the project site to determine if the Virus Protection Software will be contractor supplied or Government Furnished.
****

[Provide Virus Protection Software consisting of the project site's standard virus protection software complete with a virus definition update subscription] [Virus Protection Software will be furnished by the Government].

2.3.16.14 Disk Imaging (Backup) Software

****
NOTE: Coordinate with the project site to determine SECTION 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION if the Disk Imaging (Backup) Software will be contractor supplied or Government Furnished.
****

[Provide Disk imaging (backup) software capable of performing a bare-metal restore (imaging and restoring to a new blank hard drive such that restoration of the image is sufficient to restore system operation to the imaged state without the need for re-installation of software).] [Provide Disk imaging (backup) software consisting of the project site's standard disk imaging software.] [Disk imaging (backup) software will be furnished by the Government.]

2.3.16.15 Supported Field Control Protocols

****
NOTE: one of the integration methods for legacy systems is to use a protocol driver (a 'software gateway') in the M&C software to integrate the legacy system, and these requirements permit the M&C Software to support protocols other than those specifically required in this specification.
****

Provide M&C Software which supports field control protocols as follows:

2.3.17 Remote Access Hardware

[Remote access outside of the installation is strictly prohibited. Remote access is permitted only from within the installation boundaries].

2.3.17.1 Hardware Requirements

Remote access hardware must be compliant with cybersecurity protocols and standards. This hardware must facilitate secure communication channels for remote monitoring, control, and maintenance activities.

2.3.17.1.1 Firewalls

Deploy advanced firewalls to segregate the MCS network from unauthorized access.

2.3.17.1.2 VPN Gateway

A Virtual Private Network (VPN) gateway must be installed to ensure encrypted communication.

2.3.17.1.3 Multi-Factor Authentication

Implement multi-factor authentication mechanisms for all remote access points.

2.3.17.2 Redundancy and Failover

For mission-critical operations, redundant hardware configurations must be employed. Failover capabilities must be automatic and tested to ensure seamless transition during hardware or network failures.

2.3.17.3 Remote Access Protocols

Secure remote access protocols must be used, including but not limited to SSH, HTTPS, and SNMPv3. These protocols must be configurable to meet specific project requirements.

2.3.17.4 Data Encryption

Data in transit must be encrypted using algorithms that meet or exceed industry standards. Options for encryption algorithms include [AES][RSA].

2.3.17.5 Hardware Maintenance

Regular maintenance schedules must be established for all remote access hardware. Firmware updates must be applied in a timely manner and in accordance with manufacturer recommendations.

2.3.17.6 Logging and Monitoring

All remote access activities must be logged and monitored in real-time. Alerts for unauthorized or suspicious activities must be configured to notify designated personnel immediately.

2.3.17.7 Compliance and Certification

Hardware and software components must be compliant with relevant industry standards and certifications, including but not limited to [NIST].

Additionally, all remote access hardware must obtain an Authority to Operate (ATO) in accordance with the cybersecurity specification outlined in the project documentation. Compliance with this specification is mandatory for system deployment and operation.

2.3.18 Data Logging and Event Recording

2.3.18.1 Types of Data to be Logged

The system must log the following types of data:

a. Voltage, current, and power factor at all critical nodes
b. Frequency at the PCC and DER
c. Status of all circuit breakers and disconnects
d. Alarms and fault conditions
e. Energy production and consumption metrics
f. Control signals sent and received
g. System mode and state transitions

2.3.18.2 Data Logging Frequency

Data must be logged at varying frequencies depending on the parameter:

a. Electrical parameters such as voltage, current, and frequency: Every [1 second][5 seconds]
b. System status and mode: Every [10 seconds][30 seconds]
c. Alarms and fault conditions: Instantaneously

2.3.18.3 Data Storage Duration

Logged data must be stored for a minimum duration based on its type:
a. Electrical parameters: [30 days][90 days]
b. System status and mode: [7 days][30 days]
c. Alarms and fault conditions: [1 year][2 years]

2.3.18.4 Data Backup and Redundancy

Data must be backed up in a secondary storage medium and must be retrievable for [3 months][6 months].

2.3.18.5 Event Recording

All significant system events, including but not limited to, fault conditions, mode transitions, and manual interventions, must be recorded with a timestamp. These records must be stored for a minimum of [1 year][2 years].

2.3.18.6 Access to Logged Data

Logged data must be accessible through the MCS Human-Machine Interface (HMI) and must also be exportable in [CSV][XML] format for further analysis.

2.3.18.7 Data Security

Logged data must be encrypted and secured in compliance with relevant cybersecurity standards, ensuring data integrity and confidentiality.

2.4 COMPUTER HARDWARE

Computers used as microgrid controllers must meet the microgrid Computer Hardware Specifications outlined herein. Computers used for visualization and historian purposes may have significant data storage and visualization requirements that few MC hardware platforms can meet. Therefore, computers with lower performance criteria than the MC are selected here. All computers used on a microgrid must abide by the following minimum requirements:

a. Designed and manufactured by an ISO 9001 US based certified manufacturer
b. UL Listed to U.S. and Canadian safety standards
c. Rack- or panel-mount
d. Error-correcting code (ECC) memory
e. No moving parts
f. MTBF minimum of 10 years.
g. Meet or exceed IEEE 1613
h. Operating System with minimum of 10 years remaining support
i. Time synchronization to better than 4 ms, optional IRIG-B
j. Two or more DVI-D ports with support for up to 3 monitors
k. PCIe expansion slots
l. SSD hard drive, sized to accommodate 10 years of data storage or IEEE 2030.8, whichever is longer.
m. Dual power supplies, powered to the same DC standards as the MCS controller above
n. Two or more Ethernet RJ45 ports
o. Alarm contact for annunciation
p. Optional RAID for hot swap data storage
q. Optional Conformal coating for harsh environments.
r. Cold, Operational: IEC 60068-2-1, Severity Level: 16 hours at -40°C
s. Cold, Storage: IEC 60068-2-1. Severity Level: 16 hours at -40°C
t. Damp Heat, Cyclic: IEC 60068-2-30, Severity Level: 12 + 12-hour cycle 25° to 55°C, 6 cycles, >93% relative humidity
u. Damp Heat, Steady: IEC 60068-2-78, Severity Level: 40°C, 240 hours, >93% relative humidity
v. Dry Heat, Operational: IEC 60255-1, Severity Level: 16 hours at 60°C (E3-1505M CPU), 16 hours at 75°C (E3-1505L CPU)
w. Dry Heat, Storage: IEC 60255-1, Severity Level: 16 hours at 85°C
x. Vibration: IEC 60255-21-1, Severity Level: Endurance Class 2

2.5 COMPUTER SOFTWARE

All software used on the Computer Software Specifications must have the following attributes:

a. Backup installation on storage media outside the computer, such as USB or other storage device.
b. License information and purchase warranty clearly documented.
c. Product service bulletins and service patches free of charge.
d. No mandatory service fees for continuity of service.
e. Be provided by a long standing reputable company with a history of supporting their software.
f. A obsolescence plan must be provided, including the viable software alternatives should the primary software company go out of business.
g. Configuration/settings/ or code must be provided for all software integrated into the microgrid control system.

2.5.1 Web Services - API access

Public web access is strictly prohibited on DoD microgrid systems. Refer to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS for additional requirements

2.6 RACKS AND ENCLOSURES

2.6.1 Enclosures

****

NOTE: In outdoor applications specify Type 3 unless hosedown of the enclosure is anticipated, in which case specify Type 4.

For retrofit projects in older mechanical rooms or where hosedown of the enclosure is anticipated specify Type 4 enclosures. Type 4 provides a greater degree of protection in dirty and wet environments than does Type 2.

The Enclosure Keys are needed by the project site DPW.

****

Enclosures supplied as an integral (pre-packaged) part of another product are acceptable. Provide two Enclosure Keys for each lockable enclosure on a single ring per enclosure with a tag identifying the enclosure the keys operate. Provide enclosures meeting the following minimum requirements:

2.6.1.1 Outdoors

For enclosures located outdoors, provide enclosures meeting NEMA 250 [Type 3][Type 4] requirements.

2.6.1.2 Mechanical and Electrical Rooms

For enclosures located in mechanical or electrical rooms, provide enclosures meeting NEMA 250 [Type 2][Type 4] requirements.

2.6.1.3 Other Locations

For enclosures in other locations including but not limited to occupied spaces, above ceilings, and in plenum returns, provide enclosures meeting NEMA 250 Type 1 requirements.

2.6.2 Equipment Racks

Provide standard 482 mm 19 inch equipment racks compatible with the electronic equipment provided. Racks must be either aluminum or steel with bolted or welded construction. Steel equipment racks must be painted with a flame-retardant paint. Guard rails must be included with each equipment rack and have a copper grounding bar installed and grounded to the earth.

PART 3 EXECUTION

Provide QA/QC control documents including an explanation of their audit points, both internal and external. All phases of the project must be included and the documents must include pre-construction QC checklist, post-construction QC checklist and closeout QC checklist. The Contractor's QC Representative must verify each item in the Checklist and initial in the provided area to indicate that the requirement has been met. The QC Representative must sign and date the Checklist prior to submission to the Government. QC checklists must indicate quality control checks of major system functionality.

3.1 PLANNING

Prior to commencement of any work, prepare and submit a Comprehensive Execution Plan delineating the approach, methodology, and sequence of all activities necessary to execute the project in accordance with the specified requirements and schedule. All elements of the project, including but not limited to design, procurement, installation, integration, testing, and commissioning are included in the plan. Ensure that all requisite permits, approvals, and notifications have been obtained in a timely manner. Coordination is required with all relevant stakeholders, including the Government, utility companies, and other contractors, to ensure that all work is executed in a harmonized and orderly manner, minimizing disruptions and optimizing resource utilization.

3.2 DEVELOPMENT

Following approval of the detailed design, proceed with the procurement of all necessary materials, equipment, and services in accordance with the approved BOM and in compliance with the specified standards and requirements. Execute the installation, integration, and testing of the supplier specific system in accordance with the approved plans, designs, and testing plan. Ensure that all work is executed by qualified personnel in accordance with the best practices, and that all necessary measures are taken to ensure the safety, quality, and integrity of the system and surrounding installations. Upon successful completion of all testing and verification activities, coordinate with the Government and Commissioning Authority for the formal commissioning and handover of the supplier specific system, ensuring that all necessary documentation, training, and support are provided as required.

3.3 FACTORY TESTING

Conduct the Factory Test at a location and time approved by the Government. The Government will witness the factory test. If the system fails a portion of a test, the Government will determine whether the entire test or only the portion that failed must be repeated.

Perform factory testing of the MCS as specified. Provide personnel, equipment, instrumentation, and supplies necessary to perform required testing. Provide written notification of planned testing to the Government at least [21] [ ] days prior to testing, and do not give this notice until after receiving written Government approval of the specific Factory Test Procedures.

3.3.1 FACTORY TESTING COMPLIANCE

Factory testing procedures must be in compliance with IEEE 2030.8, IEEE Standard for the Testing of Microgrid control systems. Normative (enforceable) language within this specification requires a number of mandatory tests, as in the Tables below.

Table 3.1: IEEE 2030.8 Table 1, steady state grid connected scenarios

Initial Conditions	Initiating Events	Measures
POI breaker is closed Dispatch orders and objectives Power system state; this includes the breaker statuses, power flow conditions, and unbalance loads Expected minimum, average, and maximum export and import of P and Q Expected minimum, average, and maximum load levels Combinations of dispatchable and non-dispatchable DER	Power system disturbances including upstream or microgrid open or short circuit conditions Trip of DERs Setpoint step change Start and stop of largest load Action of all voltage control devices	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Table 3.2: IEEE 2030.8 Table 2, steady state islanded scenarios

Initial Conditions	Initiating Events	Measures
POI breaker is open Dispatch orders and objectives Power system state; this includes the breaker statuses, power flow conditions, and unbalance loads Expected minimum, average, and maximum load levels Combinations of dispatchable and non-dispatchable DER	Power system disturbances including microgrid open or short circuit conditions Trip of DERs Setpoint step change Start and stop of largest load Action of all voltage control devices Total P and Q load decreased/increased or DER contributions increased/ decreased to the point at which each DER is forced to anticipated minimum/ maximum production levels	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Table 3.3: IEEE 2030.8 Table 3, planned islanding transition scenarios

Initial Conditions	Initiating Events	Measures
POI breaker is closed Dispatch orders and objectives Power system state; this includes the breaker statuses, power flow conditions, and unbalance loads Expected minimum, average, and maximum export and import of P and Q Expected minimum, average, and maximum load levels Combinations of dispatchable and non-dispatchable DER	Receive planned islanding command	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Table 3.4: IEEE 2030.8 Table 4, Unplanned islanding transition scenarios

Initial Conditions	Initiating Events	Measures
POI breaker is closed Dispatch orders and objectives Power system state; this includes the breaker statuses, power flow conditions, and unbalance loads Expected minimum, average, and maximum export and import of P and Q Expected minimum, average, and maximum load levels Open circuit, short circuit, or system voltage or frequency deviations from contractual ride-through requirements. Combinations of dispatchable and non-dispatchable DER	Unplanned POI disconnection	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Initial Conditions	Initiating Events	Measures
POI breaker is open System de-energized in all cases Start with all DER available or constrained (see NOTE 2) All loads connected or disconnected	Black start requested	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Table 3.5: IEEE 2030.8 Table 5, Reconnection test scenarios

Initial Conditions	Initiating Events	Measures
POI breaker is open Dispatch orders and objectives Power system state; this includes the breaker statuses, power flow conditions, and unbalance loads Expected minimum, average, and maximum export and import of P and Q Expected minimum, average, and maximum load levels Combinations of dispatchable and nondispatchable DER Frequency and voltage difference across the POI out of specification Live/live, live/dead, dead/dead bus scenarios to be tested Start with constrained DER capacity (ramp rate or other constraints making the reconnection difficult.) All non-dispatchable DERs set at the highest and lowest power needs for the test. Use time varying loads or DER in some cases Microgrid load greater than total DER capacity	Reconnection signal received	V, f, P, Q, settling time, overshoot, and SS values within contractual requirements and equipment limitations.

Normative (enforceable) language within this specification requires a specific set of data collection for each test, as in the Tables below.

Table 3.6: IEEE 2030.8 Table C.1, Minimum data collection

Type of data collection	Minimum time synchronized accuracy	Minimum sample rate	Minimum amplitude accuracy	Required data to collect	Required to meet IEEE 2030.7
Sequence of events (SOE) records	One quarter power system cycle (0.004166 s for a 60 Hz system)	One quarter power system cycle.	N/A	Digital data only. Examples are: Switching device (breaker, recloser, and switch) open and close status, commands, protection elements, control outputs and interlocks	Yes
Event oscillography (OSC)	One quarter power system cycle	One quarter power system cycle	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes
Continuous data collection (CDC)	One quarter power system cycle	100 ms	1% of nominal voltage and 20 times nominal current	Voltage and current of all phases	Yes

All testing must adhere to normative field data collection at Level 3, per the IEEE standard section C.2 repeated below.

Level 1 - Data must be collected at and on both sides the POI for any microgrid with one DER.

Level 2 - Data must be collected at every DER and POI for any microgrid with two or more DER.

Level 3 - Data must also be collected at the load(s) and the DER for any load greater than 50% of the largest DER and for any single load larger than 10% of the maximum total power consumed by the microgrid.

3.3.2 FACTORY TEST SETUP

Perform a Factory Test to demonstrate the capability of the proposed control system solution to meet the requirements of project specifications.

Design the Factory Test Setup to represent the system as it will be fielded and to demonstrate the capability of the system to meet the requirements of the project specification.

Perform the Factory Test using equipment and software of the same manufacturer, model and revision as will be used for the specified project. At a minimum:

a. Include at least one of each model of electronic instrumentation, metering, control, relay, IO, gateway, router, and control device to be used on the project.
b. Include at least one network of each type to be used on the project.
c. All electronics must be programmed as close as possible to how they are intended to be installed.
d. Include hardware in the loop simulation that emulates some portion of the facilities. Include testing of overload, islanding, short circuit faults, open circuit faults, restoration, load acceleration, frequency collapse, voltage collapse, black starting, dispatch, load shedding, loss of DER, loss of load feeder, load swings, PV shading, and more. Black start modeling must show both cold load pickup and transformer inrush analysis. Data collection and testing sequences will be sufficient to self-certify compliance with IEEE 2030.8.
e. Include a representative set of project points as shown on the project design points schedules.
f. Demonstrate a minimum [20%, 80%] of the design Sequences of operation and control.
g. Demonstrate black start within parameters of "Island-Mode Black Start Capability" as specified in this section.

3.3.3 Factory Test Procedures

Submit Factory Test Procedures Include the following information, at a minimum, to document the factory test setup:

a. System one-line block diagram of equipment used in the factory test identifying computers (servers and workstations), network hardware, processor or controller hardware, and other instrumentation including, but not limited to, sensors, actuators, test signal generators, and meters.
b. System communication architecture diagram of the setup. If the test setup differs from the field, then a summary of the differences between the factory and field communication architectures.
c. System data flow diagram of the setup. If the test setup differs from the field, then a summary of the differences between the factory and field communication data flow diagrams.
d. System timing riser diagram identifying timing distribution and signal converters to include [IRIG-B][NTP][ ].
e. System hardware description used in the factory test.
f. System software description used in the factory test.
g. Points Schedules for each controller showing the configuration to be used during the test. Points Schedules must include the following information at a minimum: device address, point descriptions, network point names and types, hardware point types, settings and ranges including units.
h. Required passwords for each operator access level.
i. List of other test equipment.

j. Test procedures. The test procedures must consist of detailed instructions
for test setup, execution, and evaluation of test results. Within the procedures define location of tests, milestones for the tests, and identify simulation programs, equipment, personnel, facilities, and supplies required.

3.3.4 Factory Test Report

Upon completion of the Factory Test provide a Factory Test Report documenting the Factory Test. Include a copy of the Factory Test Procedure, and copies of the executed test procedures separated by test. For each test, include date performed and identify the Government representative who witnessed and approved the test. If a portion of any test failed, document the failure and corrective action.

Submit the Factory Test Report within 7 calendar days after completing the tests. Obtain approval for the test before shipping the unit. Ensure factory test reports bear the signature of an official authorized to certify on behalf of the MCS manufacturer that the system meets the specified requirements as outlined in the "Factory Testing" paragraph. Present test reports in booklet form, tabulating factory tests and measurements performed upon the system's installation and testing. The reports must state the Contractor's name and address, the project name and location, and list the specific requirements being certified.

Document and submit all nonconformances and track them to ensure they are resolved acceptably. The documentation method will vary based on the nonconformance type, detection point, and detection method.

Document and submit serious, critical, and/or major nonconformances through a formal inspection, testing, and validation procedure. Submit these procedures before conducting inspections, testing, or validation.

The supplier must within submitted reports indicate whether the withstand certification is based on actual testing of assembled components or on calculation. Additionally, the supplier must validate and endorse the design documentation and implementation technically.

3.4 Real Time Hardware in the Loop (HIL) Testing

Real time hardware in the loop factory testing [is/is not] required for the project. High risk, complex, or large microgrid projects [may][is not permitted to] be tested while attached to an operational microgrid used by [the customer][government facilities][mission]. To include:

HIL Simulation of the power system, DERs, breakers, transformers, inverters, and LTC/OLTC must be completed for each operational state. Each test must include the following fidelity:

[a. Full fidelity: 80 microsecond or faster update interval solution of the multiple difference equations solving the electromagnetic equations. This to show accurate results in faults, protection, mechanical equipment, inverter dynamics, exciter saturation, inrush phenomena, Power flow solutions.][Partial fidelity: 500 millisecond or faster update interval. This to show accurate results only in power flow solution.]

b. Relays, I/O modules, and controllers connected to the HIL model including metering, status, and control signals.

c. Real time models must be validated in a report. Validation to include proof of accurate response of mechanical and electrical characteristics of a power system.
d. Real time HIL models must show the MCSS in full operation under conditions such as overload, islanding, short circuit faults, open circuit faults, restoration, load acceleration, frequency collapse, voltage collapse, black starting, dispatch, load shedding, loss of DER, loss of load feeder, load swings, PV shading, and more.
e. Black start modeling must show both cold load pickup and transformer inrush analysis.
f. Data collection and testing sequences will be sufficient to self-certify compliance with IEEE 2030.8.

3.5 EXISTING CONDITIONS

Prior to the installation of the microgrid controller system, a comprehensive Site Assessment Survey must be conducted and a site assessment survey submitted to evaluate the existing conditions and infrastructure. The assessment aims to provide essential information for designing and implementing the microgrid controller system in a manner that optimally integrates with the site's existing infrastructure.

3.6 ASSESSMENT CONSIDERATIONS

The site assessment survey is to include, but not be limited to, the following key factors:

a. Electrical Infrastructure: A thorough evaluation of the existing electrical infrastructure, including the condition of switchboards, distribution equipment, transformers, and interconnection points that must be controlled by the microgrid control system. Any necessary upgrades or modifications required for the integration of the microgrid control system must be identified.
b. Utility Interconnection: Examination of the utility interconnection point and assessment of its compatibility with the microgrid control system. Coordination with the utility provider, as needed, to ensure a seamless interface.
c. Environmental Conditions: Assessment of environmental conditions, including climate, temperature extremes, humidity, and exposure to elements and possible impact of these conditions on the microgrid control system's components as well as protection measures must be provided.
d. Structural Readiness: Evaluation of the structural readiness of buildings or support structures where microgrid components are intended to be installed. This includes structural integrity assessments and any necessary modifications to accommodate the system.
e. Safety Compliance: Verification of compliance with safety codes and regulations for existing electrical infrastructure, ensuring that safety standards are met when integrating the microgrid control system.
f. Access and Clearance: Assessment of access routes, clearance requirements, and space availability for equipment installation. Any obstructions or constraints that may affect the installation process are to be identified and addressed.

3.6.1 Documentation and Reporting

The findings of the site assessment are documented and reported in the site assessment survey. The documentation must include, but not be limited to, the following:

a. Site Assessment Report: A detailed report outlining the existing conditions, including photographs, measurements, and descriptions of the site's electrical infrastructure, environmental conditions, structural readiness and other noteworthy findings.
b. Recommendations: Recommendations for necessary modifications, upgrades, or adjustments to the existing conditions to facilitate the seamless integration of the microgrid control system.
c. Safety Compliance Report: A report confirming the compliance of the existing electrical infrastructure with safety codes and regulations. If non-compliance issues are identified, a plan for bringing the infrastructure into compliance must be included.
d. Clearance and Space Requirements: Documentation specifying the required access routes, clearance areas, and space allocations for equipment installation.

The Assessment report is submitted within [21][ ] days of the assessments.

3.7 FUTURE EXPANSION CAPABILITIES

The MCSS design documents must show the following attributes associated with future expansion.

Microgrid designer must select technology that is ready for incremental design, procurement, installation, commissioning, test, and maintenance. The following attributes are required:

a. Incremental design. Future DER of any sort (generator, inverter, renewable, storage, etc) and configured within acceptable operational modes (See DER mode selection chapter) must be shown to operate islanded and grid connected while simultaneously paralleled to any DER proposed by the present design. Protocol capability of the specified microgrid control system must use established standard protocols which are expected to be supported by future DER including Modbus or MIL-STD-3071.
b. Incremental procurement. DER, switchgear, controllers, relays, and any equipment with microprocessors must be designed in packages that can be purchased separately at different times/years and with backwards compatible guarantees of interoperability.
c. Incremental installation. DER, switchgear, controllers, relays, and any equipment with microprocessors procured incrementally must be capable of being installed without dependency on other equipment and must have backwards compatible guarantees of interoperability.
d. Incremental commissioning. DER, switchgear, controllers, relays, and any equipment with microprocessors installed incrementally must be capable of being commissioned without dependency on other equipment and must have backwards compatible guarantees of interoperability.
e. Incremental test. DER, switchgear, controllers, relays, and any equipment with microprocessors commissioned incrementally must be capable of being tested without dependency on other equipment and must have backwards compatible guarantees of interoperability.
f. Incremental maintenance. DER, switchgear, controllers, relays, and any equipment with microprocessors commissioned incrementally must be capable of being maintained without dependency on other equipment and must have backwards compatible guarantees of interoperability.

3.8 DRAWINGS AND CALCULATIONS

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NOTE: Two types of system communication architecture diagrams are mandatory for all microgrids. These are required for the audit, performance validation, maintenance, testing, and RMF.

A system communication architecture (aka 'architecture') diagram. This is a detailed block diagram or system architecture diagram illustrating the overall structure and hierarchy of the microgrid control system to include all physical ports (e.g. RJ45 or DB9) and all communication cables in the system. Clouding of network infrastructure is not allowed.

A data flow diagram (DFD) illustrating all virtual connections and the intent of the physical layer communications architecture to include protocols used and a summary of the data transmitted on each communication channel. IO point lists further elaborate on the contents of these DFD channels.

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3.8.1 Network Bandwidth and Usage Calculations

Provide MCS Network, RI/O and HMI networks Bandwidth Usage Calculations for a normally loaded and a heavily loaded control system. Provide Calculations for network traffic at the HMI Server and master PLCs. A heavily loaded network is characterized as one performing the following activities simultaneously:

a. Trending a number of points equal to the specified minimum monitoring and control software trending capacity at 15-minute intervals.
b. Trending (for loop tuning) 20 points at 2 second intervals.
c. Viewing 500 points via workstations with a 5 second update interval.
d. Transmitting load shed commands to 2,000 devices in a 1 minute interval.
e. Viewing of 10 system display graphic screens of 50 points each via browsers. A normally loaded network is characterized as one performing the following activities simultaneously:
f. Trending 500 points equal at 15-minute intervals.
g. Viewing 100 points via workstations with a 5 second update interval.
h. Transmitting load shed commands to 200 devices in a 1 minute interval.
i. Viewing of 2 system display graphic screens of 50 points each via browsers.

3.8.2 Draft As-Built Drawings

Provide Draft As-Built Drawings consisting of Points Schedule drawings for the entire MCS and an updated Contractor Design Drawings including details of the actual installed system as it is at the conclusion of Start-Up and Start-Up Testing.

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NOTE: The design documents must include the design

version of the drawings listed below. The intent is to require the contractor to update the documents as necessary based on the specific components selected.
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The Contractor Design Drawings required to include, at a minimum:

a. Electrical Layout Diagram illustrating the major components within the microgrid boundary and how they are interconnected both electrically and via communication networks. It includes the layout of all DERs and their connections.

b. Electrical Schematics including detailed single-line and three-line system diagrams that provide a comprehensive view of the electrical distribution system, depicting how each component is electrically connected within the microgrid.

c. Control Logic Diagrams outlining the logic used to control the operation of the microgrid, highlighting the flow of control signals among different devices and systems.Diagrams must be in accordance with ISA 5.2.

d. Functional Block Diagrams which show the basic functions of the microgrid system and how they interact, breaking down complex system behaviors into simpler, functional parts.

e. Panel Layouts as detailed diagrams showing the layout of control panels, including the arrangement of components such as controllers, meters, and protective devices, as well as the location of HMI components.

f. Cable and Conduit Routing Plans that specify the paths for electrical cables and conduits, ensuring that all components are properly connected and that the routing complies with safety and operational requirements.

g. DER Integration Plans documenting how various existing and new DERs are integrated into the microgrid, including considerations for interoperability, control, and energy management.

h. Communication Interconnection Diagram including a visual representation of the communication network within the microgrid, detailing how different devices and systems communicate with one another.

i. Communication Functional Block Diagrams per standard IEC 61131-3 which depict the functional aspects of communication within the microgrid, showing the flow of data and control signals between devices.

j. Data Flow Diagram illustrating how data moves through the microgrid system, identifying the sources, paths, and destinations of data, and how it is used for control and decision-making.

k. System IO Points List for all points monitored and interfaced.

In addition to the details shown in the design drawings, the as-built drawing must include:

a. IP address(es) as applicable for each piece of network hardware.
b. IP address for each server, workstation, and printer.
c. Network identifier (name) for each printer, computer server and computer workstation.
d. CEA-709.1D address (domain, subnet, node address) for each CEA-709.1D TP/FT-10 to IP Router.

Provide Draft As-Built Drawings upon the completion of Start-Up and Start-Up Testing, and Final As-Built Drawings upon completion of PVT Phase II.

3.9 INSTALLATION REQUIREMENTS

3.9.1 General

Start installation after Government acceptance of the Product Data and Shop Drawings. Install system components as shown and specified in accordance with the manufacturer's instructions and provide necessary interconnections, services, and adjustments required for a complete and operable system. Communication equipment and cable grounding installed to preclude ground loops, noise, and surges from adversely affecting system operation. Fiber Optic cables and wiring in exposed areas, including low voltage wiring but not including network cable in telecommunication [racks][rooms], installed in metallic raceways as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Adjust or replace devices not conforming to the required accuracies. Factory sealed devices are replaced (rather than adjusted).

3.9.2 Isolation, Penetrations, Clearance

The MCS must be completely installed and ready for operation, as specified and shown. Dielectric isolation must be provided where dissimilar metals are used for connection and support. Penetrations through and mounting holes in any building exteriors must be made watertight. Holes in concrete, brick, steel and wood walls must be drilled or core drilled with proper equipment; conduits installed through openings must be sealed with materials which are compatible with existing materials. The MCS installation must provide clearance for control-system maintenance by maintaining access space between coils, and other access space required to calibrate, remove, repair, or replace control-system devices. The control-system installation must not interfere with the clearance requirements for any other system maintenance such as electrical or mechanical devices.

3.10 INSTALLATION OF EQUIPMENT

Install equipment as specified, as shown and as required in the manufacturer's instructions for a complete and fully operational control system.

3.10.1 Vibration and Seismic Control

All equipment and the installation of equipment covered by this specification must comply with the seismic requirements as specified in Section 26 05 48 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT

3.10.2   Wire and Cable

System components and appurtenances must be installed in accordance with NFPA 70, manufacturer's instructions and as shown in drawing set. The raceways shown in the drawings are diagrammatic and must be coordinated with equipment being installed. Additional raceways not shown in the drawings but required for proper system operation must be provided and installed. Utilize separate raceways to segregate cables for redundant equipment and systems. Raceway sizes may be increased to accommodate manufacturer's cables or to accommodate supplied cables that have different outside diameter than cables specified. Costs associated with raceway changes must be borne by the Contractor. Cables must comply with the equipment manufacturer's requirements. Should specified cables not meet manufacturer's requirements, install appropriate cable complying with manufacturer's requirements. Costs associated with cable substitution based on manufacturer's requirements must be borne by Contractor. Necessary interconnections, services, and adjustments required for a complete and operable signal distribution system must be provided. Components must be labeled in accordance with TIA-606.

Conduits, outlets and raceways must be installed in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. The wiring must be installed in accordance with TIA/EIA-568.1-D and as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Wiring, and terminal blocks and outlets must be marked in accordance with TIA-606. Cables must be installed in the same cable tray, utility pole compartment, or floor trench compartment with ac power cables. Cables not installed in conduit or wireways must be properly secured and neat in appearance.

3.10.2.1   LAN Cables and Connecting Hardware

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NOTE: Include in the project specification any of the following UFGS for the appropriate BTC: Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM, Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP).

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Provide data transmission systems for communication [between PLCs][and][between PLCs and the central station][and][server] as specified in [Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM][Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP)] and as indicated.

3.10.2.2   Unshielded Twisted Pair Patch Panels

Patch panels must be mounted in equipment racks with sufficient modular jacks to accommodate the installed cable plant plus 10 [20] percent spares. Cable guides must be provided above, below and between each panel.

3.10.2.3   Fiber Optic Patch Panels

Patch panels must be mounted in equipment racks with sufficient ports to accommodate the installed cable plus 10 [20] percent spares. A slack loop of fiber must be provided within each panel. Loop must be 3 feet in length. The outer jacket of each cable entering a patch panel must be secured to the panel using clamps or brackets specifically manufactured for the purpose of preventing movement of the fibers within the panel. DIN rail mounted patch panels must also be installed where building fiber enters MCS enclosures or switchgear.

3.10.2.4 Equipment Racks

Equipment racks/cabinets must be provided and installed in accordance with Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

3.10.2.5 Rack Mounted Equipment

Equipment to be rack mounted must be securely fastened to racks by means of the manufacturers recommended fasteners.

3.10.2.6 Termination

Cables and conductors must sweep into termination areas; cables and conductors must not bend at right angles. The manufacturer's minimum bending radius must not be exceeded. When there are multiple system type drops to individual panels, relative position for each system must be maintained on each system termination block or patch panel.

3.10.2.7 Unshielded Twisted Pair Cable

Each pair must be terminated on appropriate outlets, terminal blocks or patch panels. No cable is allowed to be unterminated or contain unterminated elements. Pairs must remain twisted together to within the proper distance from the termination. Conductors must not be damaged when removing insulation. Wire insulation must not be damaged when removing outer jacket.

3.10.2.8 Shielded Twisted Pair Cables

Each cable must be terminated on panel-mounted connectors. Cables must be grounded at patch panels using manufacturer's recommended methods. Shield braid is to be continuous to connector braid terminator. Wire insulation must not be damaged when removing shield.

3.10.2.9 Fiber Optic Cable

Each fiber must have connectors installed. The pull strength between the connector and the attached fiber must not be less than 25 pounds. The mated pair loss, without rotational optimization, must not exceed 1.0 db.

3.10.3 Pathways

Shop drawings must provide a comprehensive plan for the establishment of pathways within the microgrid control system. This plan must include:

Cable Routing: A detailed layout of cable routing throughout the system, ensuring that cables are organized, secured, and protected from potential damage.

Conduit and Tray Systems: Conduit and cable tray systems, including materials, sizes, and installation methods, to accommodate various cables and wires.

Separation of Services: Clear separation of power and communication cables to prevent interference and ensure safety.

Support Structures: Provision for support structures, such as cable trays, ladder racks, and mounting brackets, to securely fasten cables and prevent sagging or stress on the cables.

Conduit Sealing: Proper sealing of conduits to prevent the entrance of moisture, dust, or contaminants.

Cable Management Devices: Utilization of cable ties, clamps, and routing accessories to maintain cable organization and prevent tangling.

Cable Guards: Installation of cable guards or covers to protect cables from physical damage or accidental contact.

EMI/RFI Shielding: Shielding measures to protect sensitive communication cables from electromagnetic and radio frequency interference.

3.10.4 Identification

All cables and microgrid control equipment within the microgrid control system must be appropriately identified and labeled for easy maintenance. Labels must include cable/equipment type, function, and any other relevant information to facilitate troubleshooting and system management.

3.10.5 Grounding and Bonding

Signal distribution system ground must be installed in accordance with TIA-607 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Equipment racks must be connected to the electrical safety ground.

3.10.6 Reference Voltages

Equipment racks and equipment contained within must be securely connected to the electrical safety ground to maintain a safe reference voltage.

3.10.7 Grounding

Design documents must provide detailed calculations and designs of system grounding, lightning grounds, static grounding, equipment grounding, safety grounding, as appropriate.

System grounds on microgrids are primarily designed to prevent equipment overvoltage. Microgrid systems without a system ground reference commonly experience overvoltage conditions due to single phase loads, faults, switching transients, or unbalanced capacitive coupling between phases and earth ground. In a three phase system not designed for ungrounded operation and with no reference to ground the phases can achieve damaging voltage levels. Overvoltage conditions cause surge arrestors, lightning arrestors, or insulation flash over in primary equipment. Once the first phase finds ground during this flash over, the other phases can rise to 173% of nominal voltage.

Although a microgrid may only have one perceived island, for grounding systems the design engineer must identify two types of isolated ground islands.

Electrically (galvanically) isolated grid sections such as when a circuit breaker is open. Be advised that in most four wire systems the neutral stays in service with three pole disconnection means, e.g., circuit breakers and disconnects.

Magnetically isolated grid sections such as occur at every transformer with certain transformer configurations.

Designs must show each ground island, either galvanically or magnetically formed, to have their own system ground(s).

Grounding must adhere to one or more of the following code standards:

NEC (NFPA 70) rules apply to system grounding below 1000V. Above 1000V, grounding systems are subject to utility jurisdiction. Designer to base their 1000 V and above designs on the local utility standards. In the absence of utility standards, designs must comply with IEEE standards C62.92.

3.10.8 Surge Protection

Equipment connected to ac circuits must be protected against or withstand power-line surges. Equipment protection must meet the requirements of IEEE C62.41.1 and IEEE C62.41.2. Fuses are not to be used for surge protection.

Digital and analog inputs and outputs must be protected against surges induced on control and sensor wiring installed outdoors. The inputs and outputs must be tested in both the normal and common mode using the following two waveforms: The first waveform must be 10 microseconds by 1000 microseconds with a peak voltage of 1500 volts and a peak current of 60 amperes. The second waveform must be 8 microseconds by 20 microseconds with a peak voltage of 1000 volts and a peak current of 500 amperes.

3.11 APPLICATION

Provide MCS capable of for real-time monitoring, control, optimization, and dispatch of DER in both grid-connected and islanded modes. The controller must provide advanced functionalities to interface with a wide range of DERs, ensuring safe, secure, and resilient operation of the microgrid.

3.12 INTEGRATION OF FIELD CONTROL SYSTEMS

3.12.1 Install Control Hardware

All hardware components of the microgrid control system, including processors, I/O modules, communication devices, and interface units, must be installed in compliance with manufacturer recommendations and IEEE 2030.8 requirements. .

3.12.2 Add Field Control System

Integration with the field control systems of various DERs must be performed through standardized communication protocols such as Modbus, IEC 61850, and DNP3. Suitable gateway devices or protocol converters may be employed if direct integration is not feasible.

3.12.3 Configure Software

The microgrid control system software must be configured to match the specific requirements of the project, including DER types, ratings, communication settings, and desired operational modes. Necessary database parameters like DER setpoints, limits, and grid interconnection requirements must be accurately entered.

3.13 FIELD QUALITY CONTROL

3.13.1 Tests

3.13.1.1 Dispatch Functions

Validate the dispatch capability of each DER by sending appropriate control commands. Confirm ramp rate controls, start/stop sequences, and setpoint adjustments as per design.

3.13.1.2 Transition Functions

Test transition between grid-connected and islanded modes and vice versa. Validate the smooth switchover without power interruptions or excessive transients.

3.13.1.3 Grid-Following Synchronization

Using the external grid as reference, each DER in unison or in tandem, as outlined in the sequence of control, must synchronize, and connect either at the point of interconnection, or the point of connection for each DER.

For a central-plant type architecture, define the sequence of operation with regard to powering the connected loads (via external grid or via DER before interconnection).

Ensure that the voltage waveforms of the DERs are in phase with the external grid to allow for proper synchronization and connection. Ensure that the connection type (delta or wye) of the DERs matches that of the external grid to ensure proper synchronization and connection.

3.13.1.4 Islanded Grid-Forming Synchronization

During islanded operations designate a primary DER as the grid-forming unit and validate its ability to form the grid. All other DERs must be checked for synchronization capability to this primary source. In alternative designs where all DERs are grid-forming with droop characteristics, test and validate each DER's capability to operate in this mode.

3.13.1.5 Load-Following, Load-Shedding, and Energy Management

Validate the controller's capability to adjust DER dispatch in response to real-time load variations. Test and confirm the load-shedding schemes, ensuring prioritized shedding of non-critical loads during supply shortages. The controller must also demonstrate efficient energy management, optimizing DER dispatch for economic operations.

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NOTE: Consideration should be given to the possible power quality, fault current, and voltage drop issues based on which DER is selected as primary during island mode. As the power flow varies based on load and generation, the system may be required to dynamically adjust the protection.

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3.13.2 Examination and Inspection

Prior to commissioning, complete the following examinations and inspections:

a. Initial Inspection: Prior to commissioning, conduct an initial inspection to ensure that all system components, including hardware and software, are installed correctly and securely.

b. Safety Checks: Ensure that all safety protocols and mechanisms are in place and functioning as intended. This includes emergency shutdown procedures, overcurrent protection, fault detection, and isolation measures.

c. Cybersecurity Testing: Ensure cybersecurity standards are met for the system to ensure resilience against cyber threats in accordance with Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS, paragraph CYBERSECURITY AUDITING.

d. Data Logging and Reporting: Verify data logging and reporting mechanisms, ensuring that the system records and reports relevant operational data accurately.

e. Redundancy and Failover Testing: Confirm the functionality of redundancy and failover mechanisms, guaranteeing seamless operation in the event of component failures or disruptions.

f. Environmental Testing: Assess the system's ability to withstand environmental conditions and ensure compliance with environmental standards.

g. Documentation Review: Review all documentation related to the system's configuration, settings, and operational procedures to ensure completeness, accuracy for reference during commissioning process.

3.13.3 Manufacturer Field Startup and Service

Obtain the services of a MCS manufacturer's representative experienced in the installation, adjustment, and operation of the equipment specified. The representative must supervise the installation, adjusting, and testing of the equipment. At a minimum, the services of manufacturer's representatives for the MCS equipment, central station, HMI, software, and data collection/report generation software must be provided.

3.14 STARTUP TESTING

Test all equipment and perform all other tests necessary to ensure the system is installed and functioning as specified. Prepare and submit a Startup Testing Plan prior to testing and Startup Testing Report documenting all tests performed and their results and certifying that the system meets the requirements specified.

Do not begin the startup testing until after receipt of written permission by the Government representative for base maintenance, based on Government approval of the startup testing Plan and Draft As-Built Drawings.

Perform telecommunications cabling inspection, verification, and performance tests in accordance with TIA-568-C.1, TIA-568-C.2, and TIA-568-C.3. Submit telecommunications cabling testing report for any cables requiring testing.

3.14.1 Testing Wire and Cable

Materials and documentation to be furnished under this specification are subject to inspections and tests. Terminate all components prior to testing. Equipment and systems will not be accepted until the required inspections and tests have been made, demonstrating that the signal distribution system conforms to the specified requirements, and that the required equipment, systems, and documentation have been provided.

3.14.1.1 Unshielded Twisted Pair Testing

Test all metallic cable parts that have not been put into operation previously for proper identification and continuity. All opens, shorts, crosses, grounds, and reversals are to be corrected. Verify correct color coding and termination of each pair in the control system cabinets and at the end-device. Test horizontal wiring from end-to-end, including the termination device and including any modular jacks. Test backbone wiring end-to-end, including termination devices, from terminal block to terminal block. Complete these tests, and correct all errors, before starting any other tests.

3.14.1.2 Category 5E Circuits Testing

Test all Category 5E circuits that have not been put into operation previously using a test set that meets the Class II accuracy requirements of TIA/EIA-TSB-67. Use the Basic Link Test procedure of TIA/EIA-TSB-67. Cables which contain failed circuits must be replaced and retested to verify the standard is met.

3.14.1.3 Shielded Twisted Pair Wiring Testing

Test configurations that have not been put into operation previously or have been labeled as spare. Test for continuity, opens, shorts, correct pin configuration. Verify DC resistance for both pair-to-pair and wire-to-shield types. Verify all cable lengths. Test near end crosstalk from 722 kHz to 300 MHz.

3.14.1.4 Fiber Optic Cable Testing

Perform optical fiber field inspection tests via attenuation measurements on any existing or new cable to be utilized that has not been put into operation previously or has been previously labeled as spare. Provide test results where applicable. Remove failed cables from project site upon attenuation test failure.

3.14.1.5 Inspection

Visually inspect UTP and optical fiber jacket materials for UL or third-party certification markings. Inspect cabling terminations to confirm color code for T568A or T568B pin assignments. Inspect cabling connections to confirm compliance with TIA-568-C.1, TIA-568-C.2, and TIA-568-C.3. Visually confirm Category 5E, marking of outlets, cover plates, outlet/connectors, and patch panels.

3.14.1.6 Final Verification Tests

Perform verification tests for UTP and optical fiber systems after the complete telecommunications cabling and workstation outlet/connectors are installed.

Data Tests. Connect to the network interface device at the demarcation point. Log onto the network to ensure proper connection to the network.

3.14.2 Protective Relays Communications Testing

Verify software for communications and programming of protective relays to operate correctly in accordance with the manufacturer's published instructions. Include verification of time signal to relays, local and remote access to relay settings, and SER and ER functionality verification.

3.14.2.1 Points List Testing

All input and output points indicated on the typical points schedule must be tested for proper operation from the HMI and head-end workstation to the end. Test the following:

a. All devices with discrete (digital) output are checked for all energized and response states. The device outputs are confirmed and documented in an energized state and a de-energized state. Any changes in output status are documented.
b. All trouble and fault alarms with discrete (digital) outputs must be confirmed as normally closed, open on alarm.
c. All devices requiring a change in mechanical signal input must be checked and calibrated to provide the correct discrete (digital) output.

For analog transducers, calibration is required. Calibration for digital devices is not required if the factory test report shows calibration has been completed. Calibrate each analog instrumentation device connected to the control system control network by making a comparison between the reading at the device and the display at the HMI and head end workstation, using a standard at least twice as accurate as the device to be calibrated. Analog points must be tested at 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent of full scale.

Verify operation of systems in the specified failure modes upon MCS network failure or loss of power and verify that systems return to control system control automatically upon a resumption of control system network operation or return of power.

Verify system automatically performs a cold start (with the head end and controllers off-line) upon application of power and is in full operation as specified within [ ] [five minutes].

Verify system automatically performs a warm start (with head end off-line and controllers on-line) upon application of power without human intervention and is in full operation as specified within 15 minutes. Verify the head end servers review and enable programs that must be running at that time, including the restart of any automatic control programs resident at the head end servers.

Verify system recovers from power failure. When a power failure occurs at the head end or field panel, the system must automatically start upon restoration of power and the programs are to be restarted in a manner to assure an orderly resumption. Include a restart program based on detection of power failure at the head end MCS controller and distributed controllers. Upon restoration of power to the head end MCS controller and distributed controllers, verify the controllers obtain time of day from the system's real time clock, restart properly, and restore loads to the state at time of power failure, or to the state as commanded by time programs or other overriding programs. Include start time delays between successive commands to prevent demand surges or overload trips.

Energize all equipment with motors to confirm proper operation, rotation (phasing), inrush currents, full load current.

Provide a startup testing report documenting all startup tests describing results of functional tests, diagnostics, calibrations, and commissioning procedures including written certification to the Government that the installed complete system has been calibrated, tested, adjusted, and commissioned and is ready to begin the PVT. The report must also include a copy of the approved PVT procedure.

3.15 PERFORMANCE VERIFICATION TESTING (PVT)

Refer to following specifications for details: Section 25 08 10 UTILITY MONITORING AND CONTROL SYSTEM TESTING. Provide a PVT Procedure using the test procedures in this section, modifying the procedures and adding tests as appropriate to develop procedures that test all requirements of the project specifications. The test procedures must consist of detailed instructions for test setup, execution, and evaluation of test results. When developing additional procedures, provide the same information and fields as shown in the Test Template. The PVT must be performed in three phases:

Phase I Testing (Standalone Test)
Phase II Testing (Integration Test)
Phase III Testing (Endurance Test)

Provide a PVT Plan including system documentation and PVT Procedures. Include the following system documentation in the PVT Plan:

a. Copies of the most recent draft as-built drawings for the system, including but not limited to one-line drawings and Points Schedules [as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC] showing device address, point descriptions, network point names and types, hardware point types, settings and ranges including units.
b. Copies of manufacturer's product data sheets when needed to demonstrate compliance with project requirements. For example, provide data sheets showing that surge protection requirements have been met.
c. Operation or user manuals for all software and all DDC Hardware to be tested.
d. List of test equipment.

Submit the PVT Testing Procedures, including a control system performance verification test equipment list that lists the equipment to be used during performance verification testing. For each piece of equipment include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration. At a minimum this is expected to include primary or secondary current injections test kits.

Provide PVT testing procedures using the test procedures in this Section, modifying the procedures and adding tests as appropriate to develop procedures that test all requirements of the project specifications.

Include detailed instructions for test setup, execution, and evaluation of test results.

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NOTE: Coordinate with the project site to determine if government witness of PVT is required, or if there is a third party commissioning agent acting on behalf of the Government.

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Do not start the PVT until after receipt of written permission by the Government representative for base maintenance, based on Government approval of the PVT Procedure and Draft As-Built drawings. [The Government will witness each phase of PVT.][The Government's third-party commissioning agent will witness each phase of PVT]

PVT Phase I demonstrates compliance of the control system with the contract documents. Using test plans and procedures approved by the Government, demonstrate all physical and functional requirements of the project. Show, step-by-step, the actions and results demonstrating that the control systems fully and correctly implement the sequences of operation and control. PVT for surge protection is not required to include introducing a surge to the equipment; surge protection may instead be demonstrated through product documentation.

Conduct testing during the most electrically demanding season, whether that be peak summer or peak winter, based on locality. At the completion of PVT Phase I, Phase II, and Phase III testing, and in accordance with the project schedule and project sequencing, provide reports documenting all PVT testing including all approved test procedures with test results indicated on the procedures, and a record of all actions taken to address PVT test failures.

3.15.1 Phase I Testing (Standalone Test)

Operational tests must to be completed and include testing device operation within the intended subsystem. All states included in the subsystem must be tested. All failover states must be documented. All communications within the subsystem must be tested. All tests are to be documented.

Unit tests are to be completed on each MCS device and include testing device operation as a standalone device. The devices must be tested energized.

Performing a sequence of operations test to the extent possible in the given subsystem must include all sequences specified. All failover states must be tested within each standalone subsystem.

At the completion of PVT Phase I, and in accordance with the project schedule and project sequencing, submit the PVT Phase I Testing Report documenting test procedures, failures and repair actions taken during PVT Phase I.

3.15.2 Phase II Testing (Integration Test)

Once the MCS has been tested as a standalone system, an Integration test must be performed. The integration test must include a re-performance of the entire sequence of operation, testing of all logic, communications testing, verification of accuracy and functioning of all graphics within the HMI, confirmation of the integrity of the control structure, and confirmation of all inputs and outputs. The integration test must be performed to the extent of verifying the full functional performance of the microgrid control system meets all design criteria and functionality specified here, in the drawing package and the sequence of operations.

At the completion of PVT Phase II, and in accordance with the project schedule and project sequencing, submit the PVT Phase II Testing Report documenting test procedures, failures and repair actions taken during PVT Phase II.

3.15.3 Phase III Testing (Endurance Test)

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NOTE: The intent of the Endurance Test is to ensure the microgrid control system is burned in and able to operate without internal component failure. The test can be operated in island mode, grid mode, or black start mode.

Coordinate the off-grid testing requirements with the equipment provided (and specified elsewhere in the UFGS). Where carbon-emitting generators are used, coordinate EPA ratings and emissions requirements.

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Complete an endurance test as part of the PVT in which the system is operated continuously for [24-hours][48-hours][one-week][___] without failure. The test can be operated in island mode, grid mode or black start mode. During the endurance test trend all points shown as requiring a trend on the Points Schedule for the entire duration of the endurance test. If insufficient buffer or storage capacity exists to trend the entire endurance test, offload trend logs during the course of the endurance test to ensure that no trend data is lost. If the control system specification includes bandwidth requirements for bandwidth usage on a non-IP network, measure and record the network bandwidth usage on each non-IP channel during the endurance test.

If the system experiences any failures during the endurance test portion of the PVT, repair the system and repeat the endurance test portion of the PVT until the system operates continuously and without failure for the specified endurance test period. At the completion of PVT Phase III, and in accordance with the project schedule and project sequencing, submit the PVT Phase III Testing Report documenting test procedures, failures and repair actions taken during PVT Phase III.

3.16 TRAINING

3.16.1 General

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NOTE: Select the video record option where site and security allows.

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Conduct Operators and Maintenance training courses for designated personnel in the Operation and Maintenance of the system as specified. The training must be oriented to the specific system being installed under this contract. Deliver training manuals for each trainee with [two] [ ] additional copies for archival at the project site. [Record training sessions to video and deliver digital video files to Governmetn on CD after completion of Training program.]Furnish all audiovisual equipment and all other training documentation and supplies. Copies of any training materials must be delivered to the Government either as a part of the printed training manuals or on the same media as that used during the training sessions. Training materials must also be included in the O&M instructions. A training day is defined as [eight][] hours of classroom instruction, including two 15-minute breaks and excluding lunchtime, Monday through Friday, during the daytime or night shift in effect at the training facility. For guidance in planning the required instruction, assume that attendees have a high school education or equivalent, and are familiar with utility systems. Approval of a planned training schedule must be obtained from the Government at least 30 days prior to the training. Submit all Training Documentation for record at project closeout.

3.16.2 Operators Training

The first course must be taught at the project site for a minimum of three 8-hour training days during or after field testing, but before commencing the PVT. A maximum of 6 [ ] personnel will attend the course. No one single part of the training given during this course is allowed be counted toward completion of the PVT. The course must be include instruction on the specific hardware configuration of the installed system and specific instructions for operating the installed system. Upon completion of this course, each student must be able to start the system, operate the system, recover the system after a failure, and describe the specific hardware architecture and operation of the system.

This course must include guided practical demonstrations for:

a. Instructional overview of system operation.
b. Detailed instruction for each mode of operation, demonstrating steady state operation and monitoring via HMI, and initiation of each SOC accessible from that state in accordance with the paragraph "MIcrogrid Control System Sequences of Control"
c. Control system management instruction to train users on the complete HMI. Demonstrate each distinct screen and provide written guide for what each displayed element represents and the funtions executed by selecting them.
d. Safety Procedures including essential safety protocols, review of alarm types and reporting methods, and recovery or restart demonstration for each category of alarm.
e. Maintenance and troubleshooting demonstration as outlined in paragraph "TROUBLESHOOTING AND DIAGNOSTICS".

3.16.3 Maintenance Training

The maintenance course must be taught at the project site within thirty days after completion of the PVT for a period of one training day. A maximum of 6 [ ] personnel will attend the course. The training must include:

a. Physical layout of each piece of hardware.

b. Thorough understanding of the microgrid control system and various modes of operations.

c. Troubleshooting and diagnostics procedures.

d. Repair instructions.

e. Preventive maintenance procedures and schedules.

f. Calibration procedures.

3.17 MAINTENANCE AND SERVICE

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NOTE: The maintenance and service to be provided by the Contractor for the duration of the IDIQ or maintenance contract is specified in this paragraph. The Maintenance and Service may need to be a separate bid item funded by O&M funds.

Some/many of these Maintenance and Service requirements may not apply if the UMCS networking equipment and supporting infrastructure is Government furnished equipment and maintained by the Government.The requirements here generally assume that the contractor is permitted access to the system and equipment, but the applicability of this assumption will vary site-by-site. It's critical to coordinate with the project site to determine to what extent the contractor will be responsible for system and equipment maintenance. Some notes have been included with bracketed text to provide general guidance, but careful editing of this entire subpart is needed.

Requirements should be coordinated with "WARRANTY MANAGEMENT" in Section 01 78 00 CLOSEOUT SUBMITTALS

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Perform inspection, testing, cleaning, and part or component replacement as specified and as required to maintain the new or existing warranty. Furnish labor, supervision, tools, materials, equipment, transportation, and management necessary to provide maintenance, service and repair for the MCS in accordance with the requirements as specified. Maintain, and repair devices connected to and used by the MCS in accomplishing its control and monitoring functions. This work includes inspection, testing, cleaning, lubrication, adjustment, calibration, and part or component replacement as specified. Work includes providing necessary preventive and unscheduled maintenance and repairs to keep the MCS operating as specified, and accepted by the Government, and other services as specified during the duration of work. Work must comply with manufacturer's recommendations and industry standards. Provide technical support via telephone during regular working hours.

3.17.1 Work Coordination

Coordinate all work activities related to the microgrid control system with other trades and parties involved in the project to ensure smooth and efficient installation and operation. This coordination must include regular communication with subcontractors and suppliers, coordination of installation, testing, and commissioning schedules, and collaboration with facility operators and managers to minimize disruptions during work.

3.17.2 Work Control

Maintain a clean and safe working environment throughout the installation and testing of the microgrid control system. Specific requirements including regular cleanup of work areas and removal of debris, protection of equipment and components from environmental factors, dust, and debris and implementation of safety measures to protect personnel during construction and testing.

3.17.3 Working Hours

Adhere to working hours and schedules defined in the project plan and in accordance with any state or local laws. Any deviation from the established working hours must be communicated and approved in advance to ensure minimal disruption to the facility's operation.

[3.17.4 Equipment Repairs

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NOTE: Coordinate with the project site to determine if equipment (computers and control hardware) repair will be done by the contractor or by local staff, and to what extent. If the equipment is Government furnished then the contractor may not be allowed access to some/all of the equipment for repair. Address Information Assurance (IA) or other equipment access requirements in "Access To UMCS Equipment" below.

Select repair times below.

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Initiate and complete equipment repairs within the following time periods, where time periods are measured as actual elapsed time from first notification, including working and non-working hours:

a. for non-redundant computer server hardware, initiate within [4] [_____] hours and complete within [8] [_____] hours.

b. for non-redundant computer workstation hardware, initiate within [4] [_____] hours and complete within [8] [_____] hours.

c. for redundant computer server hardware, initiate within [36] [_____] hours and complete within [5] [_____] days.

d. for redundant computer workstation hardware, initiate within [2] [_____] days and complete within [5] [_____] days.

e. for active (powered) control hardware, initiate within [4] [_____] hours and complete within [6] [_____] hours.

f. for cabling and other passive network hardware, initiate within [16] [_____] hours and complete within [5] [_____] days.

Repair is the restoration of a piece of equipment, a system, or a facility to such condition that it may be effectively used for its designated purposes. Repair may be overhaul, reprocessing, or replacement of nonfunctional parts or materials or replacement of the entire unit or system.

]

3.17.5   Replacement, Modernization, Renovation

Provide options and recommendations for the replacement, modernization, or renovation of microgrid control system equipment and components as needed, ensuring the continued efficiency and reliability of the system over time.

3.17.6   Access to MCS Equipment

Provide clear guidelines and procedures for authorized personnel to access microgrid control system equipment for maintenance, inspection, and repairs. Security measures and access control must be implemented to safeguard sensitive equipment.

3.17.7   Records, Logs, Progress Reports

Maintain detailed records, logs, and progress reports throughout the construction and testing phases, documenting work activities, test results, and project milestones. These records must be included in the O&M Instructions.

3.17.8   Periodic Maintenance and Inspection

Outline requirements for periodic maintenance and inspection of the microgrid control system to ensure its ongoing functionality and reliability. Comprehensive O&M Instructions must be compiled to guide facility personnel in these tasks.

3.17.9   Preventive Maintenance Requirements

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NOTE: If the contractor will not be responsible for Preventive Maintenance keep only the bracketed text requiring a plan "detailing" preventive maintenance (note this may include software maintenance as well as hardware maintenance). Otherwise remove "[detailing]" and keep the other bracketed text.

Delete the requirement for written requests to reschedule maintenance if not required by the project site.

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[Perform maintenance procedures as described below, or more often if required by the equipment manufacturer.] [Prepare a Preventive Maintenance Work Plan included in the Operations and Maintenance submittal as specified.]

3.17.9.1   Preventive Maintenance Work Plan

Prepare a Preventive Maintenance Work Plan [to schedule] [detailing] all required preventive maintenance. Obtain Government approval of the Work Plan as specified in paragraph PROJECT SEQUENCING.[Strictly adhere to the approved work plan to facilitate Government verification of work.][If it is necessary to reschedule maintenance, make a written request to the Government detailing the reasons for the proposed change at least five days prior to the originally scheduled date. Scheduled dates will be changed only with the prior written approval of the Government.]

[3.17.9.2 Semiannual Maintenance

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NOTE: Coordinate with the project site to determine whether or not to include the requirements for Semiannual Maintenance. See also above notes regarding maintenance of Government furnished equipment and access requirements.
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Perform the following Semiannual Maintenance as specified:

a. Perform data backups on all Server Hardware.

b. Run system diagnostics and correct diagnosed problems.

c. Perform fan checks and filter changes for MCS hardware.

d. Perform all necessary adjustments on printers.

e. Resolve all outstanding problems.

f. Install new ribbons, ink cartridges and toner cartridges into printers, and ensure that there is at least one spare ribbon or cartridge located at each printer.

][3.17.9.3 Maintenance Procedures

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NOTE: Coordinate with the project site to determine whether or not to include the Maintenance Procedures requirement (in whole or in part). See also above notes regarding maintenance of Government furnished equipment and access requirements.

Select whether notice must be given for maintenance that will result in downtime (off-line) or for any maintenance that MAY result in downtime. A selection of 'will' is recommended unless the project site requests otherwise.

Select appropriate down-times and notice times.
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3.17.9.3.1 Maintenance Coordination

Coordinate any scheduled maintenance event that [will][may] result in component downtime with the Government as follows, where time periods are measured as actual elapsed time from beginning of equipment off-line period, including working and non-working hours:

a. For non-redundant computer server hardware, provide [14] [_____] days notice, components must be off-line for no more than [8] [_____] hours.

b. For non-redundant computer workstation hardware, provide [7] [_____] days notice, components must be off-line for no more than [8] [_____] hours.

c. for redundant computer server hardware, provide [7] [_____] days notice, components must be off-line for no more than [36] [_____] hours.

d. For redundant computer workstation hardware, provide [4] [_____] days notice, components must be off-line for no more than [48] [_____] hours.

e. For active (powered) control hardware, provide [14] [_____] days notice, components must be off-line for no more than [6] [_____] hours.

f. For cabling and other passive network hardware, provide [21] [_____] days notice, components must be off-line for no more than [12] [_____] hours.

3.17.9.3.2 Software/Firmware

Software/firmware maintenance includes [____] [operating systems,]application programs, and files required for the proper operation of the MCS regardless of storage medium. User (project site) developed software is not covered by this contract, except that the MCS software/firmware must be maintained to allow user creation, modification, deletion, and proper execution of such user-developed software as specified. Perform diagnostics and corrective reprogramming as required to maintain total MCS operations as specified. Back up software before performing any computer hardware and software maintenance. Do not modify any parameters without approval from the Government. Properly document any approved changes and additions, and update the appropriate manuals.

[3.17.9.3.3 Network

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NOTE: Network maintenance should only be required for Contractor furnished networks. If using a Government furnished network delete the requirement.

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Network maintenance includes testing transmission media and equipment to verify signal levels, system data rates, errors and overall system performance.

]]3.17.10 Service Call Reception

Establish procedures for receiving and processing service calls related to the microgrid control system. These procedures must ensure timely response to service requests and efficient troubleshooting.

3.17.11 Service Call Work Warranty

The contractor must provide a warranty for service call work performed on the microgrid control system. The terms and conditions of this warranty must be detailed in the contract documents.

3.17.12 Warranties and Guarantees

Provide a warranty for service including service call availability to support work performed on the microgrid control system. The terms and conditions of this warranty must be detailed in the contract documents. Work is to be warrantied for a period of 1 year from on-site startup and must perform repairs to the system at no cost to the Government during this period. Include a copy of the warranty for service in the O&M Instructions.

3.18 EMERGENCY RESPONSE PLAN

Develop and submit an Emergency Response Plan that outlines procedures for responding to critical situations and ensuring the safety and reliability of the microgrid control system in emergencies. This plan must be integrated into the O&M Instructions. The emergency response plan must include procedures and responsibilities in the event of a system failure, natural disasters, or other emergencies.

3.19 TROUBLESHOOTING AND DIAGNOSTICS

Provide a comprehensive guide for troubleshooting and diagnosing issues related to the microgrid control system. Include general and specific troubleshooting procedures and incorporate into the O&M Instructions.

3.20 AS-BUILT DOCUMENTS

Prepare thorough as-built documents, submitted at the draft phas as Draft As-Built documents prior to construction, and as Final As-Built Documents included in the O&M package. The as-built documentation must provide a comprehensive record of the final installation, including precise locations of all components, wiring diagrams, cable routing, control/ladder logic, and all final as-built drawings. For each piece of equipment, include detailed specifications, manufacturer information, and relevant certification documents. This information ensures clarity during future maintenance or upgrades. The as-built documents must incorporate records of all testing and inspection activities performed during the installation and commissioning phases. For systems with software components, the as-built documentation must include detailed configurations, settings, and any custom Programming Software or Configuration Software developed or implemented. This ensures that software can be effectively maintained and updated.

3.21 ON-GOING MAINTENANCE MATERIALS

Provide any additional materials necessary to support the long-term operation and maintenance of the microgrid control system. Supply a list of recommended spare parts for the system. This list must encompass critical components, ensuring rapid replacement when necessary. Outline the availability of technical support services, including emergency contact information and response times. Procedures for acquiring and installing software and firmware updates for the microgrid control system must be provided, including recommendations for testing and implementing updates. Include the On-Going Maintenance Materials in the O&M Instructions.

3.22 PORTALS, CLOSED, OR TRANSFERRED TO GOVERNMENT

This section defines the process for closing or transferring access portals or control systems to government control. Close unneeded access portals to the microgrid control system, which may include disabling user accounts, revoking privileges, and securing the system against unauthorized access. When transferring ownership to the government, include the transfer of credentials, access control, and administrative responsibilities.

-- End of Section --