# SECTION 26 33 53 – STATIC UNINTERRUPTIBLE POWER SUPPLY

## PART 1 – GENERAL

### 1.1 RELATED DOCUMENTS

A. Drawings and general provisions of Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

### 1.2 SUMMARY

A. Section Includes:

1. Three-phase, on-line, double-conversion, static-type, UPS units with following features:
2. Rectifier-charger.
3. Inverter.
4. Controls and indications.
5. Static bypass transfer switch.
6. External maintenance bypass/isolation switch.
7. Remote monitoring provisions.
8. Battery and battery disconnect device.
9. Battery monitoring.

### 1.3 DEFINITIONS

A. EMI: Electromagnetic interference.

B. IGBT: Isolated gate bipolar transistor.

C. LCD: Liquid-crystal display.

D. LED: Light-emitting diode.

E. NiCad: Nickel cadmium.

F. PC: Personal computer.

G. SPD: Surge protection device.

H. THD: Total harmonic distortion.

I. UPS: Uninterruptible power supply.

## 1.4 ACTION SUBMITTALS

A. Product Data: For each type of UPS.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for UPS.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings: For UPS.

1. Include plans, elevations, sections, and mounting details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
4. Include diagrams for power, signal, and control wiring.

## 1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For power quality specialist.

B. Product Certificates: For each product, from manufacturer.

C. Factory Test Reports: Comply with specified requirements.

D. Product Test Reports: Indicate test results compared with specified performance requirements, and provide justification and resolution of differences if values do not agree.

E. Field quality-control reports.

F. Sample Warranties: For manufacturer's special warranties.

## 1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For UPS units to include in emergency, operation, and maintenance manuals.

## 1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: One for every 10 of each type and rating, but no fewer than one set of each.
2. Cabinet Ventilation Filters: One complete set.

## 1.8 QUALITY ASSURANCE

A. Power Quality Specialist Qualifications: Registered professional electrical engineer or engineering technician, currently certified by National Institute for Certification in Engineering Technologies, NICET Level 4, minimum, experienced in performance testing UPS installations and in performing power quality surveys like that required in "Performance Testing" Article.

B. Testing Agency Qualifications: Certified by NETA.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

## 1.9 WARRANTY

A. Special Battery Warranties: Manufacturer and Installer agree to repair or replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.

1. Warranted Cycle Life for Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, but not less than following, based on annual average battery temperature of 77 degrees F:

2. Warranted Cycle Life for Premium Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, but not less than following, based on annual average battery temperature of 77 degrees F:

B. Special UPS Warranties: Specified form in which manufacturer and Installer agree to repair or replace components that fail in materials or workmanship within special warranty period.

1. Special Warranty Period: Three years from date of Substantial Completion.

# PART 2 - PRODUCTS

## 2.1 OPERATIONAL REQUIREMENTS

1. Double Conversion, IGBT:

a. Normal Conditions: Load is supplied with power flowing from normal power input terminals, through rectifier-charger and inverter, with battery connected in parallel with rectifier-charger output. High-efficiency carrier stored trench IGBT, in both rectifier-charger and inverter circuits, provides minimum of 97 percent efficiency for UPS system at full load and minimum of 94 percent efficiency at 50 percent load.

b. Abnormal Supply Conditions: If normal supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, battery supplies energy to provide constant, regulated inverter power output to load.

c. Power Failure: If normal power fails, rectifier-charger and inverter use energy from battery to supply constant, regulated power output to load without switching or disturbance.

2. When power is restored at normal supply terminals of system, controls shall automatically synchronize inverter with external source before transferring load. Rectifier-charger shall supply power to load through inverter and simultaneously recharge battery.

3. If battery becomes discharged and normal supply is available, rectifier-charger shall charge battery. Rectifier-charger shall automatically shift to float-charge mode on reaching full charge.

4. If element of UPS system fails and power is available at normal supply terminals of system, static bypass transfer switch shall switch load to normal ac supply circuit without disturbance or interruption.

5. The output power converters shall produce up to 300 percent of rated full-load current for short-circuit clearing. Inverter shall sustain steady-state overload conditions of up to 200 percent of rated full-load current for 60 seconds in normal operation.

6. The inverter shall be capable of sustaining 150 percent of system capacity for 30 seconds while powered from battery.

7. Should overloads persist past time limitations, automatic static transfer switch shall switch load to bypass output of UPS. When fault has cleared, static bypass transfer switch shall return load to UPS system.

8. If battery is disconnected, UPS shall supply power to load from normal supply with no degradation of its regulation of voltage and frequency of output bus.

B. Manual operation includes following:

1. Turning inverter off causes static bypass transfer switch to transfer load directly to normal ac supply circuit without disturbance or interruption.

2. Turning inverter on causes static bypass transfer switch to transfer load to inverter.

C. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless static bypass transfer switch is in bypass mode. Device provides manual selection among 3 conditions described below without interrupting supply to load during switching:

1. Full Isolation: Load is supplied, bypassing UPS. Normal UPS ac input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.

2. Maintenance Bypass: Load is supplied, bypassing UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from load.

3. Normal: Normal UPS ac supply terminals are energized and load is supplied through static bypass transfer switch and UPS rectifier-charger and inverter, or battery and inverter.

D. Environmental Conditions: UPS shall be capable of operating continuously in following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance:

1. Ambient Temperature for Electronic Components: 32 to 104 degrees F.

2. Ambient Temperature for Battery: 41 to 95 degrees F.

3. Relative Humidity: Zero to 95 percent, noncondensing.

## 2.2 PERFORMANCE REQUIREMENTS

A. UL Compliance: Listed and labeled by NRTL to comply with UL 1778.

B. The UPS shall perform as specified in this article while supplying rated full-load current, composed of combination of linear and nonlinear load, up to 100 percent nonlinear load with maximum load crest factor of 3.0, under following conditions or combinations of following conditions:

1. Inverter is switched to battery source.
2. Steady-state ac input voltage deviates up to plus or minus 15 percent from nominal voltage.
3. Steady-state input frequency deviates up to plus or minus 5 percent from nominal frequency.
4. THD of input voltage is 15 percent or more with minimum crest factor of 3.0, and largest single harmonic component is minimum of 5 percent of fundamental value.
5. Load is 30 percent unbalanced continuously.

C. Minimum Duration of Supply: If battery is sole energy source supplying rated full-load UPS current at 80 percent power factor, duration of supply is 8 hours.

D. Input Voltage Tolerance: System steady-state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10 percent and minus 15 percent from nominal voltage.

E. Overall UPS Efficiency: Equal to or greater than 86 percent at 100 percent load, 85 percent at 75 percent load, and 84 percent at 50 percent load.

F. Maximum Acoustical Noise: 60 dB, "A" weighting, emanating from UPS component under condition of normal operation, measured 48 from nearest surface of component enclosure.

G. Maximum Energizing Inrush Current: Eight times full-load current.

H. AC Output-Voltage Regulation for Loads 100 Percent Unbalanced: Maximum of plus or minus 2 percent over full range of battery voltage.

I. AC Output-Voltage Regulation for Loads 100 Percent Balanced: Maximum of plus or minus one percent over full range of battery voltage.

J. Output Frequency: 60 hertz, plus or minus 0.1 percent over full range of input voltage, load, and battery voltage.

K. Limitation of harmonic distortion of input current to UPS shall be as follows:

1. Description: Rectifier-charger circuits shall limit THD to 5 percent, maximum, at rated full-load UPS current, for power sources with X/R ratio between 2 and 30. Provide tuned harmonic filter if required to meet harmonic distortion limit.

L. Maximum Harmonic Content of Output-Voltage Waveform: 5 percent rms total and 3 percent rms for single harmonic, for rated full load with THD up to 50 percent, with load crest factor of 3.0.

M. Minimum Overload Capacity of UPS at Rated Voltage: 125 percent of rated full load for 10 minutes, 200 percent for 60 seconds in normal operation, and 150 percent for 30 seconds in battery operating mode.

N. Maximum Output-Voltage Transient Excursions from Rated Value: For following instantaneous load changes, stated as percentages of rated full UPS load, voltage shall remain within stated percentages of rated value and recover to, and remain within, plus or minus 2 percent of that value within 50 ms:

1. 50 Percent: Plus or minus 3 percent.
2. 100 Percent: Plus or minus 5 percent.
3. Loss of AC Input Power: Plus or minus one percent.
4. Restoration of AC Input Power: Plus or minus one percent.

O. Input Power Factor: Minimum of 0.95 lagging when supply voltage and current are at nominal rated values and UPS is supplying rated full-load current without additional filters.

P. Output Power Factor Rating: Loads with power factor of 0.9 leading to 0.8 lagging shall not require derating of UPS. For loads with power factors outside this range, derate UPS output as follows:

1. Derate UPS maximum of 5 percent for 0.7 PF lagging.
2. Derate UPS maximum of 10 percent for 0.6 PF lagging.
3. Derate UPS maximum of 15 percent for 0.5 PF lagging.
4. Derate UPS maximum of 20 percent for range of 0.4 to 0.1 PF lagging.

Q. EMI Emissions: Comply with FCC rules and regulations and with 47 CFR 15 for Class A equipment.

## 2.3 UPS SYSTEMS

A. Description: Self-contained, battery backup device and accessories that provides 3-phase electrical power in event of failure or sag in normal power system.

B. UPS systems shall be manufactured by APC / Schneider Electric or approved equal.

C. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.

D. Enclosures: Comply with NEMA 250, Type 1, unless otherwise indicated.

E. Configuration: Multi-cabinet modular style units.

F. Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.

G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by qualified testing agency, and marked for intended location and application.

H. UPS Cabinet Ventilation: Redundant fans or blowers draw in ambient air near bottom of cabinet and discharge it near top rear.

## 2.4 RECTIFIER-CHARGER

A. Description: Voltage source converter, 12-pulse IGBT rectifier.

B. Capacity: Adequate to supply inverter during rated full output load conditions and simultaneously recharge battery from fully discharged condition to 95 percent of full charge within 10 times rated discharge time for duration of supply under battery power at full load.

C. Output Ripple: Limited by output filtration to less than 0.5 percent of rated current, peak to peak.

D. Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.

1. Response Time: Field adjustable for maximum compatibility with local generator-set power source.

E. Battery Float-Charging Conditions: Comply with battery manufacturer's written instructions for battery terminal voltage and charging current required for maximum battery life. Battery charger shall be matched to battery type supplied.

F. NiCad Battery Charger: Sense full charge by measuring rate of temperature increase. Battery charging shall be terminated when rate of temperature rise reaches 1.8 degrees F per minute. If battery reaches 140 degrees F before reaching this rate of temperature rise, charging shall terminate. Chargers that determine full charge by voltage measurement to sense 10-mV drop per cell when reaching full charge are also acceptable.

## 2.5 INVERTER

A. Description: Pulse-width modulated, IGBT with sinusoidal output. Include bypass phase synchronization window adjustment to optimize compatibility with local engine-generator-set power source.

## 2.6 CONTROLS AND INDICATIONS

A. Description: Group displays, indications, and basic system controls on common control panel on front of UPS enclosure.

B. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms include audible signals and visual displays.

C. Indications: Plain-language messages on digital LCD.

1. Quantitative indications shall include following:

a. Input voltage, each phase, line to line.

b. Input current, each phase, line to line.

c. Bypass input voltage, each phase, line to line.

d. Bypass input frequency.

e. System output voltage, each phase, line to line.

f. System output current, each phase.

g. System output frequency.

h. DC bus voltage.

i. Battery current and direction (charge/discharge).

j. Elapsed time discharging battery.

2. Basic status condition indications shall include following:

a. Normal operation.

b. Load-on bypass.

c. Load-on battery.

d. Inverter off.

e. Alarm condition.

3. Alarm indications shall include following:

a. Bypass ac input overvoltage or undervoltage.

b. Bypass ac input over-frequency or underfrequency.

c. Bypass ac input and inverter out of synchronization.

d. Bypass ac input wrong-phase rotation.

e. Bypass ac input single-phase condition.

f. Bypass ac input filter fuse blown.

g. Internal frequency standard in use.

h. Battery system alarm.

i. Control power failure.

j. Fan failure.

k. UPS overload.

l. Battery-charging control faulty.

m. Input overvoltage or undervoltage.

n. Input transformer overtemperature.

o. Input circuit breaker tripped.

p. Input wrong-phase rotation.

q. Input single-phase condition.

r. Approaching end of battery operation.

s. Battery undervoltage shutdown.

t. Maximum battery voltage.

u. Inverter fuse blown.

v. Inverter transformer overtemperature.

w. Inverter overtemperature.

x. Static bypass transfer switch overtemperature.

y. Inverter power supply fault.

z. Inverter transistors out of saturation.

aa. Identification of faulty inverter section/leg.

bb. Inverter output overvoltage or undervoltage.

cc. UPS overload shutdown.

dd. Inverter current sensor fault.

ee. Inverter output contactor open.

ff. Inverter current limit.

4. Controls shall include following:

a. Inverter on-off.

b. UPS start.

c. Battery test.

d. Alarm silence/reset.

e. Output-voltage adjustment.

D. Dry-form "C" contacts shall be available for remote indication of following conditions:

1. UPS on battery.

2. UPS on-line.

3. UPS load-on bypass.

4. UPS in alarm condition.

5. UPS off (maintenance bypass closed).

E. Emergency Power off Switch: Capable of local operation and operation by means of activation by external dry contacts.

## 2.7 STATIC BYPASS TRANSFER SWITCH

A. Description: Solid-state switching device providing uninterrupted transfer with contactor or electrically operated circuit breaker to automatically provide electrical isolation for switch.

B. Switch Rating: Continuous duty at rated full-load UPS current, minimum.

C. Input SPD: 80 kA.

## 2.8 MAINTENANCE BYPASS/ISOLATION SWITCH

A. Description: Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route flow of power to load around rectifier-charger, inverter, and static bypass transfer switch.

1. Switch shall be electrically and mechanically interlocked to prevent interrupting power to load when switching to bypass mode.
2. Switch shall electrically isolate other UPS components to permit safe servicing.
3. Switch shall electrically isolate rectifier-charger, inverter, and static bypass transfer switch from load, but shall allow primary power to UPS for testing.

B. Switch Rating: Continuous duty at rated full-load UPS current.

C. Mounting Provisions: Separate wall-mounted unit.

D. Key interlock with key that is released only when rectifier-charger and inverter are bypassed by static bypass transfer switch. Key shall be required to unlock maintenance bypass/isolation switch before switching from open (normal) position to closed position. Lock shall be designed specifically for mechanical and electrical component interlocking.

## 2.9 REMOTE MONITORING

A. Description: Communication module in unit control panel provides capability for remote monitoring of status, parameters, and alarms specified in "Controls and Indications" Article. Remote computer and connecting signal wiring are not included in this Section. Include following features:

1. Connectors and network interface units for data transmission via RS-485, Ethernet, or web-based link.
2. Software designed for control and monitoring of UPS functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of meaningful reports. Permit storage and analysis of power-line transient records. Designs for Windows applications, software, and computer are not included in this Section.

## 2.10 BATTERY

A. Description: Valve-regulated, recombinant, lead-calcium units, factory assembled in isolated compartment of UPS cabinet, complete with battery disconnect switch.

1. Arrange for draw-out removal of battery assembly from cabinet for testing and inspecting.

B. Description: Valve-regulated, premium, heavy-duty, recombinant, lead-calcium units, complete with battery disconnect switch and intercell connectors.

1. Factory assembled in isolated compartment of UPS cabinet.
2. Mount on 3-tier, acid-resistant, painted steel racks.

## 2.11 BASIC BATTERY MONITORING

A. Description: Continuous, real-time capture of battery performance data.

B. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.

C. Battery compartment high-temperature detector initiates alarm when smoke or temperature greater than 167 degrees F occurs within compartment.

D. Annunciation of Alarms: At UPS control panel and remotely.

## 2.12 SOURCE QUALITY CONTROL

A. Factory test complete UPS system before shipment. Use simulated battery testing. Include following:

1. Test and demonstration of functions, controls, indicators, sensors, and protective devices.
2. Full-load test.
3. Transient-load response test.
4. Overload test.
5. Power failure test.

B. Report test results. Include following data:

1. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.
2. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.
3. List of instruments and equipment used in factory tests.

# PART 3 - EXECUTION

## 3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for conditions affecting performance of UPS.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

C. Verify installation conditions are representative of conditions used in coordination studies for electrical system. Provide fuse protection per Section 262813 "Fuses" if required for coordination with UPS overcurrent protective device requirements.

## 3.2 INSTALLATION

A. Comply with NECA 1.

B. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

C. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

D. Maintain minimum clearances and workspace at equipment per manufacturer's written instructions and NFPA 70.

E. Connections: Interconnect system components. Make connections to supply and load circuits per manufacturer's wiring diagrams unless otherwise indicated. Apply oxide inhibitor on battery terminals.

## 3.3 GROUNDING

A. Separately Derived Systems: If not part of listed power supply for data-processing room, comply with NFPA 70 requirements for connecting to grounding electrodes and for bonding to metallic piping near isolation transformer. Comply with requirements in Section 260526 "Grounding and Bonding."

## 3.4 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification."

## 3.5 BATTERY EQUALIZATION

A. Equalize charging of battery cells per manufacturer's written instructions. Record individual-cell voltages.

## 3.6 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

B. Tests and Inspections:

1. Inspect interiors of enclosures, including following:
    a. Inspect anchorage, alignment, grounding, and required clearances.
    b. Component type and labeling verification.
    c. Ratings of installed components.
2. Test electrical and mechanical interlock systems for correct operation and sequencing.
3. Inspect bolted electrical connections for high resistance using one or more of following methods:
    a. Use of low-resistance ohmmeter per Section 7.22.2.2 of NETA ATS.
    b. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method per manufacturer's published data or Table 100.12 of NETA ATS.
    c. Perform thermographic survey per Section 9 of NETA ATS.

4. Test static transfer from inverter to bypass and back. Use normal load, if possible.
5. Test dc undervoltage trip level on inverter input breaker. Set per manufacturer's published data.
6. Verify synchronizing indicators for static switch and bypass switches.
7. Test insulated-case and molded-case breakers.
    a. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with circuit breaker closed, and across each open pole. Apply voltage per manufacturer's published data. In absence of manufacturer's published data, use Table 100.1 of NETA ATS.
    b. Perform insulation-resistance tests on control wiring for ground. Applied potential shall be 500V dc for 300V rated cable and 1000V dc for 600V rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
    c. Use primary current injection to determine long time and short time, ground fault, and instantaneous pickup, Use secondary current injection to test trip functions.
    d. Perform minimum pickup voltage tests on shunt trip and close coils per manufacturer's published data.
    e. Verify operation of charging mechanism.
    f. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, anti-pump function, and trip unit battery condition. Reset trip logs and indicators.
8. Test automatic transfer switches.
    a. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, per Section 7.22.3.1 of NETA ATS.
    b. Perform insulation-resistance tests on control wiring for ground. Applied potential shall be 500V dc for 300V rated cable and 1000V dc for 600V rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate applied voltage, follow manufacturer's recommendation.
    c. Perform contact/pole-resistance test.
    d. Verify settings and operation of control devices.
    e. Calibrate and set relays and timers per Section 7.9 of NETA ATS.
    f. Verify phase rotation, phasing, and synchronized operation as required by application.
    g. Perform automatic transfer tests.
        1) Simulate loss of normal power.
        2) Return to normal power.
        3) Simulate loss of emergency power.
        4) Simulate forms of single-phase conditions.
    h. Verify correct operation and timing of following functions:
        1) Normal source voltage-sensing and frequency-sensing relays.

2) Time delay on transfer.

3) Alternative source voltage-sensing and frequency-sensing relays.

4) Automatic transfer operation.

5) Interlocks and limit switch function.

6) Time delay and retransfer on normal power restoration.

9. Test direct current system's batteries.

   a. Verify adequacy of battery support racks, mounting, anchorage, alignment, grounding, and clearances.

   b. Inspect spill containment installation. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.

   c. Verify charger functions and alarms.

   d. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

   e. Perform load test per manufacturer's published data or IEEE 450.

   f. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.

   g. Test values.

      1) Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of lowest value.

      2) Charger float and equalize voltage levels shall be per battery manufacturer's published data.

      3) The results of charger functions and alarms shall be per manufacturer's published data.

      4) Cell voltages shall be within 0.05V of each other or per manufacturer's published data.

      5) Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of lowest value.

      6) Cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 percent between identical cells that are in fully charged state.

      7) Results of load tests shall be per manufacturer's published data or IEEE 450.

10. Test communication of status and alarms to remote monitoring equipment.

11. Load system using variable-load bank to simulate kilovolt amperes, kilowatts, and power factor of loads for unit's rating. Use instruments calibrated within previous 6 months per NIST standards.

    a. Simulate malfunctions to verify protective device operation.

    b. Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.

c. Test harmonic content of input and output current at 25, 50, and 100 percent of rated loads.

d. Test output voltage under specified transient-load conditions.

e. Test efficiency at 50, 75, and 100 percent of rated loads.

f. Test remote status and alarm panel functions.

g. Test battery-monitoring system functions.

C. The UPS system will be considered defective if it does not pass tests and inspections.

D. Record of Tests and Inspections: Maintain and submit documentation of tests and inspections, including references to manufacturers' written instructions and other test and inspection criteria. Include results of tests, inspections, and retests.

E. Prepare test and inspection reports.

## 3.7 PERFORMANCE TESTING

A. Engage services of qualified power quality specialist to perform tests and activities indicated for each UPS system.

B. Monitoring and Testing Schedule: Perform monitoring and testing in four 10-day periods, each in different season of year.

1. Schedule monitoring and testing activity with Owner, through Architect, with at least 14 days' advance notice.

2. Schedule monitoring and testing after Substantial Completion, when UPS is supplying power to its intended load.

C. Monitoring and Testing Instruments: Three-phase, recording, power monitors. Instruments shall provide continuous simultaneous monitoring of electrical parameters at UPS input terminals and at input terminals of loads served by UPS. Instruments shall monitor, measure, and graph voltage current and frequency simultaneously and provide full-graphic recordings of values of those parameters before and during power-line disturbances that cause values to deviate from normal beyond adjustable threshold values. Instruments shall be capable of recording either on paper or on magnetic media and have minimum accuracy of plus or minus 2 percent for electrical parameters. Parameters to be monitored include following:

1. Current: Each phase and neutral and grounding conductors.

2. Voltage: Phase to phase, phase to neutral, phase to ground, and neutral to ground.

3. Frequency transients.

4. Voltage swells and sags.

5. Voltage Impulses: Phase to phase, phase to neutral, phase to ground, and neutral to ground.

6. High-frequency noise.

7. Radio-frequency interference.

8. THD of above currents and voltages.

9. Harmonic content of currents and voltages above.
10. Battery cell temperature during charging.
11. Ambient temperature.

D. Monitoring and Testing Procedures for Each Test Period:

1. Exploratory Period: For first 2 days of first scheduled monitoring and testing period, make recordings at various circuit locations and with various parameter-threshold and sampling-interval settings. Make these measurements with objective of identifying optimum UPS, power system, load, and instrumentation setup conditions for subsequent test and monitoring operations.
2. Remainder of Test Period: Perform continuous monitoring of at least 2 circuit locations selected on basis of data obtained during exploratory period.
    a. Set thresholds and sampling intervals for recording data at values selected to optimize data on performance of UPS for values indicated, and to highlight need to adjust, repair, or modify UPS, distribution system, or load component that may influence its performance or that may require better power quality.
    b. Perform load and UPS power source switching and operate UPS on generator power during portions of test period per directions of Owner's power quality specialist.
    c. Operate UPS and its loads in each mode of operation permitted by UPS controls and by power distribution system design.
    d. Using loads and devices available as part of facility's installed systems and equipment, create and simulate unusual operating conditions, including outages, voltage swells and sags, and voltage, current, and frequency transients. Maintain normal operating loads in operation on system to maximum extent possible during tests.
    e. Make adjustments and repairs to UPS, distribution, and load equipment to correct deficiencies disclosed by monitoring and testing; repeat appropriate monitoring and testing to verify success of corrective action.

E. Coordination with Specified UPS Monitoring Functions: Obtain printouts of built-in monitoring functions specified for UPS and its components in this Section that are simultaneously recorded with portable instruments in this article.

1. Provide temporary use of appropriate PC and printer equipped with required connections and software for recording and printing if such units are not available on-site.
2. Coordinate printouts with recordings for monitoring performed per this article, and resolve and report anomalies in and discrepancies between 2 sets of records.

F. Monitoring and Testing Assistance by Contractor:

1. Open UPS and electrical distribution and load equipment and wiring enclosures to make monitoring and testing points accessible for temporary monitoring probe and sensor placement and removal as requested.
2. Observe monitoring and testing operations; ensure that UPS and distribution and load equipment warranties are not compromised.

3. Perform switching and control of various UPS units, electrical distribution systems, and load components as directed by power quality specialist. Specialist shall design this portion of monitoring and testing operations to expose UPS to various operating environments, conditions, and events while response is observed, electrical parameters are monitored, and system and equipment deficiencies are identified.
4. Make repairs and adjustments to UPS and to electrical distribution system and load components, and retest and repeat monitoring as needed to verify validity of results and correction of deficiencies.
5. Engage services of UPS manufacturer's factory-authorized service representative periodically during performance testing operations for repairs, adjustments, and consultations.

G. Documentation: Record test point and sensor locations, instrument settings, and circuit and load conditions for each monitoring summary and power disturbance recording. Coordinate simultaneous recordings made on UPS input and load circuits.

H. Analysis of Recorded Data and Report: Review and analyze test observations and recorded data and submit detailed written report. Include following in each report:

1. Descriptions of corrective actions performed during monitoring and survey work and their results.
2. Recommendations for further action to provide optimum performance by UPS and appropriate power quality for non-UPS loads. Include statement of priority ranking and cost estimate for each recommendation that involves system or equipment revisions.
3. Copies of monitoring summary graphics and graphics illustrating harmonic content of significant voltages and currents.
4. Copies of graphics of power disturbance recordings that illustrate findings, conclusions, and recommendations.
5. Recommendations for operating, adjusting, or revising UPS controls.
6. Recommendations for alterations to UPS installation.
7. Recommendations for adjusting or revising generator-set or automatic transfer switch installations or their controls.
8. Recommendations for power distribution system revisions.
9. Recommendations for adjusting or revising electrical loads, their connections, or controls.

I. Interim and Final Reports: Provide interim report at end of each test period and final comprehensive report at end of final test and analysis period.

## 3.8 DEMONSTRATION

A. Engage factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain UPS.

**END OF SECTION**