SECTION 266140 - UNINTERRUPTIBLE POWER SUPPLY

PART 1 - GENERAL

1.1 DESCRIPTION

A. General provisions and other electrical systems are specified in other Sections of Division 26.

B. This Section covers continuous duty, on-line, solid state uninterruptible power supply (UPS) systems.

C. This Section includes responsibilities and obligations in support of the performance verification specified in Section 260090, Electrical Performance Verification.

1.2 QUALITY ASSURANCE

A. Conform to the following:

1. UL 1778-2014(R2017).

PART 2 - PRODUCTS

2.1 GENERAL

A. The UPS shall consist of a solid state inverter, rectifier/battery charger, static bypass transfer switch, integral maintenance bypass switch, synchronizing circuitry, external battery, protective devices and accessories. The UPS shall automatically maintain AC power within the specified tolerances to the critical load, without interruption, during failure or deterioration of the normal power source.

1. The manufacturer shall design and furnish materials and equipment to be fully compatible with electrical, environmental, and space conditions at the site. The manufacturer shall include equipment to properly interface the AC power source to the intended load and the system shall be designed for unattended operation.

B. Environmental Conditions:

1. The UPS shall be designed to withstand any combination of the following environmental conditions without mechanical or electrical damage or degradation of operating characteristics:

a. Operating Ambient Temperature:

1) UPS: 0˚C to 40˚C without derating.
2) Battery: 25˚C ±3˚C.

b. Storage/Transport Ambient Temperature:

1) -20˚C to 70˚C.

c. Relative Humidity:

1) 0% to 95% noncondensing.

d. Altitude:

1) Operating: to 4000' above sea level without derating.
2) Storage/transport: to 50,000' above sea level.

2. Audible noise: maximum 72 dBA measured 5' from the unit.

C. Manufacturer: APC Galaxy VM., Liebert, Eaton.

2.2 INPUT ELECTRICAL CHARACTERISTICS

A. Voltage range: +10%, -15% of nominal.

B. Frequency range: ±5%.

C. Rectifier walk-in/inrush current limiting: 20% to 100% of full rated load over 15 seconds (adjustable).

D. Sub-cycle magnetizing inrush: not to exceed 2-3 times normal full load input current.

E. Power factor: minimum 0.85 lagging at full load with nominal input voltage.

F. 2-Step Rectifier Input Current Limit:

1. Step 1: factory set at 115% (adjustable 100% to 125%) full load input current.
2. Step 2: factory set at 100% (adjustable 85% to 125%) for on-generator operation.

G. 2-Step Battery Charge Current Limit:

1. Step 1: factory set at 10% (adjustable 1% to 25%) maximum battery charging current.
2. Step 2: factory set at 1% (adjustable 1% to 25%) maximum battery charging current.

H. Maximum input harmonic distortion shall be below 3% at full load and nominal input voltage.

2.3 OUTPUT ELECTRICAL CHARACTERISTICS

A. Load rating: 104% continuous load rating at 104˚F for any combination of linear and nonlinear loads at the capacity of the connected modules.

B. Voltage regulation: ±0.5% for balanced loads, ±2% for 50% unbalanced loads.

C. Voltage adjustment range: ±5% manually.

D. Automatic line drop compensation: adjustable 0% to +5% of nominal voltage.

E. Frequency regulation: 0.1%.

F. Voltage Transients:

1. 20% load step: ± 4%.
2. 50% load step: ±4%.
3. 100% load step: ±5%.
4. Loss of/return to AC input power: ±1%.
5. Transfer to/from bypass: ±4%.

G. Output voltage transients: voltage transients shall be limited to a maximum deviation from nominal system output volts of plus or minus 5% with recovery to within 1% of the nominal output voltage within one electrical cycle (16 ms) for each of the following conditions. Limits shall apply to any UPS load within the UPS rating and frequency shall be maintained at 60 Hz ±0.1 Hz. The system shall not transfer to bypass under these conditions (except item 3).

1. 100% load step.
2. Loss or return of AC input power, momentary sags, surges or spikes on the input to the UPS (all three phases or single phase).

3. Uninterrupted transfer of the critical load to and from the UPS output and bypass power line (manually initiated or automatic).

H. Voltage Harmonic Distortion:

1. Maximum 4% RMS total, maximum 2% any single harmonic.
2. Maximum 5% RMS total for up to 100% nonlinear load.

I. Overload at Full Output Voltage with ±2% Voltage Regulation:

1. 104% continuously.
2. 125% of full load for 10 minutes.
3. 150% of full load for a minimum of 30 seconds.
4. Overloads in excess of the UPS rating on an instantaneous basis or the overload time periods listed above shall cause the static bypass transfer switch to reverse transfer and allow the bypass AC input source to supply the necessary load fault clearing current required.

J. Current limit: 155% full load current.

K. Fault clearing: sub-cycle current of at least 300% but not more than 500% of normal full load current (when bypass is not available).

2.4 SYSTEM COMPONENTS

A. Rectifier/Battery Chargers:

1. Input current reflected harmonic distortion: input current THD shall be less than 10% THD at full load.
2. AC input current limiting: rectifier/chargers shall include a circuit to limit AC input current to an adjustable level of 100% to 125% of the full input current rating. A second circuit shall provide greater limiting, 85% to 125%, when signaled by an external contact (i.e., operation of an engine-generator set).
3. Battery charge current limit: rectifier/chargers shall include a circuit to limit battery charging current to an adjustable level of 1% to 25% of maximum battery discharge current. A second circuit shall provide greater limiting when signaled by an external contact (i.e., operation of an engine-generator set).
4. Input current walk-in: rectifier/chargers shall provide a feature that limits the total initial power requirement at the input terminals to 20% of rated load and gradually increases power to 100% of full rating over a 15-second time interval.
5. Input circuit breakers: rectifier/chargers shall have an input circuit breaker. The circuit breaker shall be of the same frame size and trip rating to supply full rated load and recharge the battery at the same time. The circuit breaker shall have an undervoltage release to open automatically when control voltage is lost.
6. Fuse protection: each AC phase shall be individually fused with fast-acting fuses so that loss of any semiconductor shall not cause cascading failures. Fuses shall be bolted to bus bars at both ends to ensure mechanical and electrical integrity.
7. DC filters: rectifier/chargers shall have an output filter to minimize ripple current into the battery. The AC ripple voltage of the rectifier DC output shall not exceed 0.5% RMS of the float voltage. The AC ripple current in the battery during float operation shall not exceed 2% RMS of the inverter full load DC current. The filter shall be adequate to ensure that the DC output of the rectifier/charger will meet the requirements of the inverter without the battery connected.
8. Battery recharge: in addition to supplying power for the load, the rectifier/charger shall be capable of producing battery charging current sufficient to replace 95% of the battery discharge power within 10 times the discharge time. After the battery is recharged, the rectifier/charger shall maintain the battery at full charge until the next emergency operation.
9. Battery equalize charge: an automatic equalize charge timer feature shall be provided to automatically apply an equalize voltage to the battery after a 30 second or longer utility outage that

generates a Battery Discharging Alarm. The duration of the equalize charge time shall be adjustable from 0 h to 72 h. Manual override shall be provided for the automatic equalize circuit.

10. Overvoltage protection: there shall be DC overvoltage protection so if the DC voltage rises to the preset limit, the UPS shall shut down automatically and initiate an uninterrupted load transfer to bypass.
11. Battery load testing: the UPS shall be capable of performing battery load testing under operator supervision. To accomplish this, the rectifier/charger will reduce charging voltage to 1.9 V per cell, to force the batteries to carry the load for a short period of time. If the curve of the battery voltage drop indicates diminished battery capacity, the UPS shall display an alarm message on the LCD. If the voltage drop indicates battery failure, the UPS shall terminate the test immediately and annunciate the appropriate alarms.
12. Runtime calibration: UPS shall be provided with this feature for re-calibration of the estimated remaining runtime

B. Inverters:

1. Inverters shall be solid-state, capable of providing rated output power and shall be a pulse width modulated 6-step design and utilize insulated gate bipolar transistors (IGBTs). The IGBTs shall not be paralleled within an inverter assembly, nor will inverter modules be paralleled within a single UPS module. The inverter shall not require an inverter output series static switch/isolator for the purposes of fault isolation or transfers to bypass.
2. Overload capability: inverters shall be able to sustain an overload across its output terminals up to 150% with ±2% output voltage regulation. The inverter shall be capable of at least 300% current for short circuit conditions. If the short circuit is sustained, the load shall be transferred to the bypass source and the inverter shall disconnect automatically from the critical load bus.
3. Output frequency: inverters shall track the bypass continuously providing the bypass source maintains a frequency of 60 Hz ±0.5 Hz. Inverters shall change the frequency (slew rate) at 0.1 Hz per second (adjustable 0.01 Hz per second to 1.0 Hz per second) to maintain synchronous operation with the bypass. This shall allow make-before-break manual or automatic transfers. If the bypass fails to maintain proper frequency, inverters shall revert to an internal oscillator which shall be temperature compensated and hold the inverter output frequency to 0.1% from the rated frequency for steady-state and transient conditions. Drift shall not exceed 0.1% during any 24-hour period. Total frequency deviation, including short time fluctuations and drift, shall not exceed 0.1% from the rated frequency.
4. Phase-to-phase balance: system logic shall provide individual phase voltage compensation to obtain phase balance of no less than ±2% under all conditions including up to 50% load unbalance, measuring against the three-phase average.
5. Fault sensing and isolation: fault sensing shall be provided to isolate a malfunctioning inverter from the critical load bus to prevent disturbance of the critical load voltage beyond the specified limits. An automatic circuit breaker shall be provided to isolate a malfunctioning inverter from the critical load.
6. Output circuit breakers: inverters shall be provided with a motor-operated circuit breaker to isolate the inverter from the critical load bus. This circuit breaker shall be of the correct frame size and trip rating to supply full load and overload current as specified herein. The circuit breaker shall work in conjunction with the bypass circuit breaker specified herein for both automatic and manual load transfers to and from bypass power.
7. Battery protection: inverters shall be provided with monitoring and control circuits to protect the battery system from damage due to excessive discharge. Inverter shutdown shall be initiated when the battery voltage has reached the end of discharge voltage. The battery end of discharge voltage shall be calculated and automatically adjusted for partial load conditions to allow extended operation without damaging the battery. Automatic shutdown based on nominal discharge time shall not be allowed.

C. Inverter Bypass Operation:

1. For times when maintenance is required or the inverter cannot maintain voltage to the load due to sustained overload or malfunction, a bypass circuit shall be provided to isolate the inverter output

from the load and provide a path for power directly from an alternate AC source. The UPS control system shall constantly monitor the availability of the inverter bypass circuit to perform the transfer. The inverter bypass circuit shall consist of a static transfer switch, a circuit breaker to isolate the inverter, and a bypass circuit breaker in parallel with the static transfer switch. The static transfer switch shall consist of two reverse-paralleled silicon controlled rectifiers (SCRs) per phase conductor that can automatically and instantaneously connect the alternate AC source to the load. The inverter isolation breaker and system bypass breaker shall be motor operated circuit breakers, self-protecting in case of a fault in the distribution system. Series rated devices shall not be used for this purpose.

2. Manual load transfers: manual load transfers between the inverter output and the alternate AC source shall be initiated from the control panel. Manually initiated transfers shall be make-before-break utilizing the inverter isolation and bypass circuit breakers. The static switch shall not be required for manual transfers.
3. Automatic load transfers: automatic load transfers between the inverter output and the alternate AC source shall be initiated if an overload condition is sustained for a time period in excess of the inverter output capability or due to a malfunction that would affect output voltage. Transfers caused by overloads only shall initiate an automatic retransfer of the load back to the inverter only after the load has returned to a level within the rating of the inverter source. The UPS system logic shall allow 0 to 5 retransfers (adjustable) within any 1 h period to prevent cyclical transfers caused by overloads.
4. Momentary overloads: in the event of a load current inrush or branch load circuit fault in excess of the inverter rating the static transfer switch shall connect the alternate AC source to the load for up to 40 ms allowing up to 1000% of the nominal rated output current to flow. Output voltage shall be sustained to the extent the alternate AC source capacity permits. If the overload condition is removed prior to the end of the 40 ms time period, the static transfer switch shall turn off and the load shall remain on inverter power. If the overload remains, then a transfer to the alternate AC source shall be completed by closing the bypass circuit breaker.
5. Protection and backfeed prevention: the critical output bus shall be protected from the flow of excess current through the static transfer switch path that may be caused by a low-impedance fault at the output of the UPS system. Each phase of the bypass circuit shall be protected by individual fuses and circuit breakers. Blown fuse monitors shall indicate when a blown fuse will prevent the static transfer switch path from being available for automatic transfers.
6. The static transfer switch shall not backfeed the UPS power to the bypass distribution system while the UPS is operating on battery during a bypass power outage. The static transfer switch shall be provided with redundant bypass power outage sensing circuits. The backfeed prevention system shall operate even if two component failures exist simultaneously. If a shorted SCR is detected, the static transfer switch shall be isolated and an alarm message shall be annunciated. The load shall remain on conditioned and protected power after detection of a shorted SCR and isolation of the static transfer switch.

D. Matching Maintenance Bypass Cabinet:

1. A make-before-break maintenance bypass shall be provided in a cabinet that matches and bolts to the UPS. Thermal-magnetic breakers shall be provided for maintenance bypass (MBB) and for maintenance isolation (MIB). The maintenance bypass shall provide the capability of transferring the critical load from the UPS inverter to the maintenance bypass and back to the UPS inverter with no interruption to the critical load.

E. Display and Controls:

1. UPS control panel: Shall be a backlit, color graphic display with choice of 18 operating languages for indication of UPS status, metering, battery status, alarm/event log and advanced operational features. The display and control panel shall be mounted on the control section door. Display panel shall be 7" color graphical type.
2. Logic: UPS system logic and control programming shall be resident in application specific integrated circuits. Rectifier, inverter and system control logic shall be solid state. Switches, contacts and relays shall only be used to signal the logic system as to the status of mechanical devices or to

signal user control inputs. Relays shall be used to isolate the logic for customer external status and alarm signaling.

3. Metered values: microprocessors shall control the display and memory functions of the monitoring system. All three phases of the three-phase parameters shall be displayed simultaneously. Voltage and current parameters shall be monitored using true RMS measurements for accurate (±1%) representation of nonsinusoidal waveforms. The following parameters shall be displayed:

    a. Input voltage, line-to-line.
    b. Input current.
    c. Battery voltage.
    d. Battery charging/discharging current.
    e. Inverter voltage, line-to-line.
    f. Inverter frequency.
    g. Bypass input voltage, line-to-line.
    h. Bypass input frequency.
    i. Load current.
    j. Load kVA.
    k. Load kW.
    l. Total operating hours shall be available on a separate display screen.

4. Power flow indications: a power flow diagram shall graphically depict whether the load is being supplied from the inverter, bypass or battery and provide, on the same screen, the status of the following components:

    a. AC input circuit breaker.
    b. Battery circuit breaker.
    c. Inverter output circuit breaker.
    d. Bypass circuit breaker.
    e. Static transfer switch (connected/disconnected).
    f. Time to overload transfer.

5. Battery status indicator: a battery status indicator shall display DC alarm conditions, shutdown voltages, the present battery voltage, and battery time remaining during discharge. A graphical representation of the battery voltage during the discharge shall be displayed. The graphical representation shall remain in the monitoring system memory until the next discharge occurs and shall be available for review of battery performance, battery charge percentage, battery time remaining and estimated time remaining.
6. Battery cycle monitor: each UPS shall have a battery cycle monitor (BCM) built into the system firmware to document the cycle service of the battery. It shall collect and retain information on the last 132 events that involved discharging the UPS battery.
7. Alarms: control panels shall report the system-level alarms listed below. An audible alarm shall be activated when any of the alarms below occur. Alarms shall be displayed in text form.

    a. Input failure.
    b. Control power failure.
    c. DC ground fault.
    d. DC capacitor blown fuse.
    e. Battery circuit breaker open.
    f. Battery discharging.
    g. Low battery warning.
    h. Low battery shutdown.
    i. DC overvoltage shutdown.
    j. Load on bypass.
    k. Automatic retransfer primed.
    l. Manual reset/retransfer.
    m. Static switch unavailable.
    n. Bypass not available.
    o. Bypass phase sequence wrong.

p. Output over/under frequency.
q. Output undervoltage.
r. Output overvoltage.
s. Overload.
t. Overload transfer.
u. Overload shutdown.
v. Reverse power.
w. Rectifier fuse blown.
x. Inverter fault.
y. Hardware shutdown.
z. Emergency off.
aa. Ambient over-temperature.
bb. Blower failure.
cc. Equipment over-temperature.
dd. Over-temperature timeout.

8. Controls: system level control functions shall be:

a. UPS/bypass transfer pushbuttons.
b. AC output voltage adjust ±5%.
c. Battery circuit breaker trip pushbutton.
d. Emergency module off pushbutton with protective cover.
e. Alarm silence.
f. Control enable pushbutton.
g. Display control pushbuttons.
h. Alarm reset pushbutton.

9. Visual displays shall provide necessary operator instructions for bringing the UPS on-line and for shutting down the equipment under normal or emergency conditions. A step-by-step procedure shall be provided for each sequence of operation.

10. Emergency power off: UPS control panels shall have a local emergency power off pushbutton with protective cover. Additionally, UPS shall be equipped with provisions for remote emergency power shut-off and dry contact input shall be used for this remote feature. Operation of the emergency power off shall cause:

a. Uninterrupted transfer of the load to bypass.
b. The input, output and battery breakers to open, completely isolating the UPS (except bypass) from power. The UPS shall include provisions for a remote emergency power off function, which either transfers the load to bypass or completely removes power from the critical bus (operator selectable) when activated.

11. Self-Diagnostics:

a. Present status screen: the control system shall monitor and display the following parameters in a present status screen:

1) Input voltage, line-to-line for all three phases.
2) Input current for all three phases.
3) Inverter voltage, line-to-line for all three phases.
4) Output current for all three phases.
5) Inverter frequency.
6) Battery voltage.
7) Battery amperes.
8) Load kVA.

b. History status file: a history status file shall contain all of the information in the present status screens except load kVA. The control system shall maintain this information in discreet 4 ms frames, updating memory on a first-in-first-out basis. This shall provide a status recall of a period of at least 256 ms: 160 ms before the malfunction fault; the fault frame; and 92 ms after the malfunction.

c. Event history file: the control system shall maintain an event history of the alarm conditions that have occurred during system operation. System memory shall be capable of storing at least 128 events for recall.
d. System status file: the control system shall monitor and display the total operating hours for the UPS system.
e. Diagnostic aids: the UPS shall be provided with the following built-in diagnostics for troubleshooting and circuit alignment aids:

1) Rectifier in control mode.
2) UPS synchronizing with critical bus load.
3) Positive DC bus ground fault.
4) Negative DC bus ground fault.
5) Bypass frequency higher than system output frequency.
6) Bypass frequency lower than system output frequency.
7) Automatic static transfer switch lockout.
8) Command given to close inverter output circuit breaker.
9) Command given to close bypass circuit breaker.
10) Command give to open inverter output circuit breaker/bypass circuit breaker.
11) Degree of overload.
12) Undervoltage release for battery disconnect switch.
13) Undervoltage release for input circuit breaker.

12. Remote alarm panel: the remote alarm panel shall have LED alarm lights. An audible alarm shall sound upon any alarm condition. The panel shall be surface mounted in a NEMA 1 enclosure. The remote alarm panel shall annunciate the following conditions:

a. Load on UPS.
b. Load on bypass.
c. Battery discharging.
d. Low battery warning.
e. Overload.
f. Ambient overtemperature.
g. System summary alarm.
h. New alarm condition.

F. Enclosures:

1. Designed to resemble a computer or computer peripheral equipment. Front access only shall be required for maintenance of the equipment.
2. Forced-air cooling, with air filters, shall be provided. Power plug-in modules shall be cooled by redundant blower motor assemblies located directly under critical components. Internal air baffles shall carry heated air from large magnetic components. Blower motors shall have sealed bearings.

G. Battery disconnect breakers: each UPS shall have a properly rated circuit breaker (500 V DC) to isolate it from the battery. This breaker shall be in a matching battery cabinet. When open, there shall be no battery voltage in the UPS enclosure. The UPS shall automatically be disconnected from the battery by opening the breaker when the battery reaches the minimum discharge voltage level or when signaled from other control functions. The UPS shall be provided with a pushbutton to trip the breaker from the control panel.

H. Battery Plant:

1. Modular battery cabinets shall be matching and adjacent to UPS cabinet.
2. Modular construction shall be made up of redundant strings per cabinet.
3. Modular battery shall allow a trained user to quickly replace the battery modules during maintenance operation.
4. Each battery string shall be monitored for voltage and temperature for use by the UPS battery diagnostics.
5. UPS shall alarm user when redundant battery string needs replacement.

6. UPS shall incorporate a battery capacity test capable of determining available runtimes.
7. The battery pack shall consist of sealed, valve regulated batteries and a properly rated circuit breaker for isolating the battery pack from the UPS. The battery cells and disconnect breaker shall be installed and housed in a NEMA 1 cabinet matching the UPS style and design.
8. The battery system shall be sized to support the nominal rated load of the UPS for a minimum of 10 min. The battery system shall provide 100% initial capacity upon delivery.
9. Batteries shall be VRLA, sealed, valve regulated with a one year full warranty and a nine year pro rata warranty under full float operation.

2.5 MODES OF OPERATION

A. Normal: inverters shall continuously supply power to the critical load. The rectifier/battery charger shall derive power from the AC source and supply DC power to the inverter while simultaneously charging the battery.

B. Emergency: when the utility AC power has failed, the critical load shall be supplied by the inverter, which, without switching, shall obtain its power from the battery. There shall be no interruption or disturbance to the critical load upon failure or restoration of the utility AC power source. When the UPS is operating on battery, a low battery voltage protection circuit shall be used to monitor the DC bus. The inverter shall be automatically turned off and the battery disconnect switch opened when the battery voltage declines to the minimum value.

C. Recharge: when the AC power has been restored, the rectifier/battery charger shall power the inverter and simultaneously recharge the battery. This shall be an automatic feature and shall cause no interruption to the critical load. When UPS is operating on AC power supplied by standby generator set the battery charge current shall be reduced to the value set by the generator manufacturer during the start-up process.

D. Bypass: when the static bypass switch is activated, the load shall be transferred to the alternate AC source without interruption. This shall be accomplished by turning the inverter off. Automatic retransfer, or forward transfer of the load to the UPS shall be accomplished by turning the inverter on. The inverter shall automatically synchronize to the alternate bypass source. Once the two sources are synchronized, the static bypass transfer switch shall automatically forward transfer the load from the bypass AC input source to the UPS inverter output. This shall be accomplished by paralleling the two sources and automatically adjusting the UPS inverter output voltage to match the bypass AC input source during transfer.

E. Maintenance bypass/test: when the UPS is taken out of service for maintenance or repair, the static bypass switch shall be used to transfer the load to the alternate source without interruption. A manual maintenance bypass switch shall be provided to isolate the UPS inverter output and static bypass transfer switch for maintenance. This shall allow the UPS to be tested or repaired without affecting load operation.

F. Power conditioner: when the battery is taken out of service for maintenance, it shall be disconnected from the rectifier/battery charger and inverter by means of an battery disconnect. The UPS shall continue to function as specified herein except for power outage protection and dynamic characteristics.

PART 3 - EXECUTION

3.1 INSTALLATION - GENERAL

A. Install the UPS system in accordance with the manufacturer's instructions.

3.2 BATTERY SYSTEM

A. Install in accordance with manufacturer's instructions.

B. Test each string for full load battery support time and provide a certified test report.

3.3 FIELD SERVICE

A. The UPS system manufacturer shall provide factory trained field service personnel to instruct the Contractor and Owner, to support the installation of the equipment, and to assist in placing the equipment into operation.

B. This service shall include a minimum of 4 separate visits by the service personnel as follows:

1. Preinstallation coordination meeting with the Contractor, Architect, Engineer, and Owner to coordinate the installation and interconnection of the various pieces of equipment specified herein.
2. For initial checkout of the installation of the UPS system.
3. Post installation start-up and testing assistance and initial instruction and training for operating personnel. This trip shall include service required to checkout the system and demonstrate the complete operation for final acceptance. Start-up and testing shall include:

    a. A complete no load functional test of the equipment to determine that the equipment has suffered no impairment in performance since factory tests were completed.
    b. A complete load test including:

        1) With each UPS module operating from the AC power source, measure and record the following under no load, 25% load, 75% load, 100% load and 110% load for 5 min and calculate efficiency.

            a) Input voltage.
            b) Input frequency.
            c) Input current.
            d) Input power factor.
            e) DC voltage.
            f) DC current.
            g) Output voltage.
            h) Output frequency.
            i) Output current.
            j) Output and input kW, including battery charger.

        2) Measurements and calculations shall demonstrate that each system performs in accordance with the electrical characteristics specified herein.

4. Record each of the following transient voltage tests:

    a. 25% load step: 50% to 75% load and return.
    b. 25% load step: 75% to 100% load and return.
    c. 40% load step: 0% to 40% load and return.
    d. 40% load step: 60% to 100% load and return.
    e. Simulate 3 failures.

5. Measure and record the UPS efficiency, with the battery on float charge and with full load at unity power factor.
6. Operate the UPS system with 100% load for a minimum of 4 h. If any failures occur, the test shall be completely restarted.

END OF SECTION 266140