# CHAPTER 3

# COMPONENT TESTING

## 3-1. Introduction to component testing

The component inspection and checks are the key to the success of any commissioning program. Each component of the system should be initially checked for damage, deterioration, and failures by a procedure using inspections and tests as defined by the specific equipment manufacturer. The equipment manuals from the manufacturer identify the minimum required receipt inspections, handling and installation procedures, drawing and wiring verification, de-energized and energized component tests, minimum testing baseline and report requirements for on-going maintenance, and requirements for repair and retesting if certain checks and tests produce unsatisfactory results. After the systems components are interconnected, the system should be checked, using de-energized and energized methods, to verify the proper interconnection and operation of the components including on/off control, system process interlocks, and protective relaying functions. Once these tests are complete, the system can be energized, and operational tests and measurements are performed. This chapter of the manual gives a typical listing of the commissioning test and testing procedures that are recommended (manufacturers' recommendations should always be incorporated into component testing) for each of the following system components before the interconnection and operation of the components as a system is verified and tested. The components/systems to be verified and tested are circuit switchers, transformers, switchgear – low voltage, switchgear – medium voltage, transfer switch, motors, ac/dc drives, generators, batteries, battery chargers, UPS systems, and cables. For equipment containing electronic components, megger testing must not be performed. However, this equipment should be tested according to manufacturer's specifications.

## 3-2. Circuit switchers

A circuit switcher is a device that consists of a disconnect switch and a circuit-breaking interrupter. They are used for switching and protecting equipment such as transformers, lines, cables, capacitor banks, and shunt reactors from small short circuit currents. The first step towards acceptance of any device is verification of nameplate data and equipment conditions. All the equipment shall be checked against nameplate, one-line, schematic, and wiring diagrams. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. Upon receipt a visual inspection of the circuit switcher and associated hardware shall be made including nameplate, parts, drawings, and condition. Any discrepancies should be sent to the manufacturer for a resolution. After installation, the circuit switcher shall be checked to ensure that it has been bolted to its permanent foundation, all shipping braces have been removed, and that it has been properly grounded. The alignment of the disconnect should be checked to ensure that the blade tongue contact enters the jaw contact on center, rotates fully and comes to rest within 1/8" of the stop. The interrupter action should be checked for proper operation as described in the operation manual. The circuit switcher shall be manually operated to check that the mechanism works smoothly and correctly. The contact surfaces should be checked for proper lubrication. The control wiring installation shall be checked per the drawings. The low pressure indicator should be checked by measuring the pressure in psig and recorded along with the ambient temperature at the time the measurement was taken and then comparing this value with the manufacturers data. Checks shall be made to insure that the grounding connections have been installed. Simulate a fault by activating the protective relay circuit and check electrical operation. Check key interlocks both mechanically and electrically. Testing shall include timing, contact resistance, contact part time, and charging motor

operation. Descriptions of these tests are found in paragraph 2-5. The timing test shall be performed at the normal operating voltage for both trip command and close command.

## 3-3. Transformers

There are two basic types of power transformers, oil-filled and dry-type. Both are subject to many of the same tests. Therefore, the following test procedures apply to both types unless otherwise noted. Since cast coil transformers are considered dry-type, the following tests also apply unless the test is noted to only apply to oil-filled transformers.

*a. Inspection on receipt.* A thorough inspection for the transformer shall be completed upon arrival and before unloading. This inspection shall include a detailed visual inspection of the external of the transformer. Since the largest transformer we are concerned with in this manual is 10 MVA, the transformers do not require impact recorder. The minimum size of transformer for impact recording is approximately 20 MVA. Oil-filled type transformers are typically shipped filled with either dry air or nitrogen. The pressure condition, nitrogen content, and dew point shall be measured before unloading of the transformer. A positive pressure should be maintained on nitrogen-blanketed transformers. The oxygen content should be less than one percent. The seals of the transformer shall be inspected to ensure that they are properly seated. For an acceptable transformer installation it is imperative that the foundation is level. This should be checked well in advance of receipt of the transformer. Upon completion of the equipment inspections, the transformer shall be unloaded and set into its final installation position. The shipping bracing shall be removed and it shall then be anchored to its foundation. The bolts (if used) securing the transformer to its foundation shall be checked to ensure that they are installed at the proper torque. For large transformers (above 20 MVA approximately), a visual inspection of the transformer internals shall be performed on air and oil-filled transformers filled with nitrogen. Transformers shipped filled with oil will not need internal inspections unless the electrical testing described below indicates a problem. Then the oil must be drained, inspection performed, and repair completed. After the repair is inspected, the transformer shall be filled with clean dielectric fluid in strict accordance with the manufacturer's instructions. The purpose of this internal inspection is to determine that no displacement has occurred in transit or during unloading. Items to be verified include the tap-changer, end braces and current transformers. This inspection must be performed with dry air in the main tank. If the transformer has been delivered filled with nitrogen, it must be evacuated from the tank replaced with dry air. Personnel performing the inspection must wear clean cotton clothing, mouth covers and oil-resistant, clean, rubber soled shoes that contain no metallic parts. All transformer nameplates, wiring, and accessories shall be visually inspected and compared against the drawings. These accessories include but are not limited to radiators, fans, bushings, and instrument controls.

*b. Installation checks.* After the preceding inspections have been completed, the transformer shall be assembled. Transformer assembly includes but is not limited to, mounting of radiators, fans, bushings, thermometers, oil level indicators, relays and expansion tank. Transformer assembly must be in accordance with manufacturer's instructions and design drawings. After all of the accessories have been installed, protection circuits shall be wired and checked. A pressure test can now be performed and the transformer filled with oil. The alarm, control, and trip settings on temperature indicators shall be inspected to verify that they are set as specified. The cooling pumps shall operate correctly, and the fan and pump motors shall have correct overcurrent protection. Operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relays shall be checked. Liquid level in all tanks and bushings shall be verified. Grounding shall be verified. Once the above is complete the following tests shall be performed on insulation resistance, dielectric absorption, polarization index, transformer turns ratio test, and power factor test. Descriptions of these tests are found in paragraphs 2-4 and 2-6. Once completed and passed, the transformer is ready for energization.

## 3-4. Switchgear – medium voltage

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. The switchgear shall be checked for completeness of assembly. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. A visual inspection of the area where the switchgear is installed should be performed to confirm that there is adequate aisle space at the front and rear of the equipment for proper ventilation, service and maintenance of the equipment. The switchgear should be checked to insure it is properly anchored to its foundation. Visually inspect that the high voltage connections are properly insulated. Electrically disconnecting contacts, machined parts, shutter, etc., should be checked for lubrication and operation. The breaker alignment and manual operation shall be checked. All blocking, supports and other temporary ties should be removed from breakers, instruments, relays, etc. Verify proper fuses are correctly placed. Verify proper voltage and phase connections. Verify correct component and installation of potential and current transformers (PTs and CTs) and control fuse size and check continuity. Also check PT and CT polarity and transformer turns ratio. Temporary wiring jumpers should be removed. Verify ground connections properly made. Verify incoming primary and secondary connections properly made and checked for shorts or undesired grounds. Verify all equipment that has been removed during assembly has been replaced. Verify relays are coordinated with other relays and protective devices on the system. Refer to relay instructions before making any adjustments. Consult local utility before making any connections to the power supply. Verify storage battery fully charged and provided with charger. Interlocks performing properly. Circuit breakers should be checked and prepared per instruction book. All filters in vent areas are clean and free of shipping or construction material. Once complete, the insulation resistance and dc hi pot test should be performed. Descriptions of these test are found in paragraph 2-4. Before performing insulation tests precautions should be made to eliminate damage to electronic controls/sensitive equipment attached to the bus. The insulation resistance test should be made on the high voltage circuit to be sure that all connections made in the field are properly insulated. A dielectric test should then be made on the high voltage circuit for one minute at the maximum test voltage. Once completed and passed, the switchgear is ready for energization.

## 3-5. Switchgear – low voltage

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. A visual inspection of the area where the switchgear is installed should be performed to confirm that there is adequate aisle space at the front and rear of the equipment for proper ventilation, service and maintenance of the equipment. The switchgear should be checked to insure it is properly anchored to its foundation. All switches, circuit breakers, and other operating mechanisms should be manually exercised to make certain they are properly aligned and operate freely. An insulation resistance test should be performed to make sure the switchgear is free from short circuits and grounds. This should be done both phase-to-ground and phase-to-phase and with the switches or circuit breakers both opened and closed. Any electrical relays, meters, or instrumentation should be checked to determine that connections are made properly and the devices function properly. Electrically exercise all electrically operated circuit breakers, and other mechanisms (but not under load), to determine that the devices operate properly. An auxiliary source of control power may be necessary to provide power to the electrical operators. Test the ground fault protection system (if furnished) in accordance with the manufacturer's instructions. Check the settings of the adjustable current and voltage trip mechanisms to confirm that they are at the proper values. Make certain that field wiring is clear of live bus and, where necessary, physically secured to withstand the effects of fault currents. Check to determine that all grounding connections are made properly. Remove all debris, scrap wire, etc., from the switchgear interior before closing the enclosure. Install covers, close doors, and make certain that no wires are pinched and that all enclosure parts are properly aligned to be tightened. Once

the above is complete perform an insulation resistance test. Before performing insulation tests precautions should be made to eliminate damage to electronic controls/sensitive equipment attached to the bus. The Insulation Resistance test is described in paragraph 2-4. Once completed and passed, the switchgear is ready for energization.

### 3-6. Transfer switch

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. The transfer switch shall be checked for completeness of assembly. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment such as loose parts and insulation damage. The Switch shall be checked for proper alignment and manual operation. The switch insulation resistance (phase-to-phase and phase-to-ground) shall be measured in normal and emergency positions. The wiring of the potential transformer to the control device should be checked for continuity and the control fuse should be checked to confirm size. The potential transformer should be tested as described in paragraph 3-3. The transfer switch should be checked for proper grounding. The timer settings should be checked against design parameters.

### 3-7. AC/DC drives

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. Drives are controllers used to vary the speed of a motor. Controllers are electronic devices that should never be megger tested. They typically come equipped with internal testing capabilities. Any diagnostic tests shall be performed as indicated in the manufacturer's manual. A visual inspection of the controller, enclosure, nameplates, connections, and drawings shall be performed. After removal of the controller enclosure cover, the controller shall be checked for physical damage and any debris from installation such as wire strands shall be removed using clean, dry, low-pressure air. All terminal connections shall be checked for tightness. The drive should be energized with no connection to the load and diagnostic test should be run. Motors should be tested separately as indicated in the motor paragraph.

### 3-8. Motors

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. A visual test of the motor shall be performed to ensure that the motor was not damaged in transit from the factory. Check that no loose items such as shaft keys, couplings, etc., are present. Check all connections for tightness and proper insulation. A mechanical test of the motor shall be performed to check that the motor is free from interference. This is accomplished by first uncoupling the motor from the driven machinery. The motor shaft is then manually rotated. The shaft should rotate freely. Once the above is complete, insulation resistance, power factor, dc hi-pot test, and polarization index tests shall be performed. The Insulation Resistance test (Megger) shall be performed for motors less than or equal to 200 hp and 480V. For motors greater than or equal to 200 hp and 2400V the Insulation Resistance and Polarization index are required. The Insulation Resistance, Polarization index, and dc Hi Pot tests are required for motors exceeding 200 hp and 2400V. On ac rotating machines, the neutral connection on the stator should be removed and a test of each winding with respect to the other two windings and ground should be obtained. After insulation resistance readings have been made, the test voltage is returned to zero and the insulation is discharged. High pot each phase separately with the other two phases and the winding temp detectors grounded. Capacitors and surge arrestors should be disconnected during this test. Once

completed and passed, the motor is ready for energized checks. A phase check should first be performed by momentarily energizing or "bumping" the motor to confirm the proper direction of rotation. This will confirm that the correct phase connections have been made. Once the correct phasing is confirmed, the motor is ready for energization.

## 3-9. Generators

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. A visual inspection shall be made to check for any loose parts, connections, or foreign materials, nameplates/parts drawings. The clearance in the generator and exciter air gap shall be checked. Be sure the generator set turns over freely. Rotate the generator rotor by hand at least two revolutions to be sure there is no interference and it turns freely. Do not apply any mechanical force to generator fan when rotating generator rotor. The insulation on all wires shall be inspected. Insulation that is loose or frayed is unacceptable and should be repaired. All wiring should be checked against the equipment drawings and all connections should be secure. Loose or dirty connections are unacceptable and should be repaired. All leads should be supported or tied to keep them from being damaged by rotating parts or sharp corners. After installation, the generator shall be checked for proper mounting and grounding. Verify that the generator is connected for the required voltage. The equipment should be inspected for any foreign objects such as remaining packing materials, loose debris including, building materials, tools, hardware, rags, paper, leaves, etc., that could be drawn into the generator and removed. All bolts and fasteners should be checked for tightness. All covers and guards should be in place and secure. Always make a thorough visual inspection to check for any obvious problems before attempting to test and run the generator. If the generator is part of a motor generator (MG), uncouple the motor. Manually rotate the motor shaft to check that the motor is free from any interference and reconnect. Check that no loose items such as shaft keys, couplings, etc., are present. Check all connections for tightness and proper insulation. Insulation resistance, polarization index and dc overpotential tests shall be performed before the generator is energized.

*a. Winding resistance test.* The main stator winding resistance is very low. A meter capable of readings in the milli-ohm range would be required. A standard VOM can be used to check for continuity, shorts or grounds. The winding resistance is measured with a dc bridge and compared with the calculated design values. This value, corrected to operating temperature is also used to calculated stator $I^2R$ loss for efficiency determination.

*b. DC overpotential test.* Perform a dc overpotential test to assess the dielectric strength of the insulation of a generator. The ac voltage used in this test is the factory test value. For stator windings this value is typically calculated to be twice the rated voltage plus 1,000. High pot each phase separately with the other two phases and the winding temperature detectors grounded. Capacitors and surge arrestors should be disconnected during this test. Measure the voltages. Now the generator can be run with no load and tested by performing the constant excitation test and the current measurements.

*c. No-load test.* This test will determine whether a problem exists in the generator or regulator system. The theory behind this test is as follows. The output voltage of a generator is dependent on its speed, design, load, and exciter input current. If the speed and exciter input are known, the output voltage at no load can be measured and compared to the design value. With the generator shut down, connect voltmeter to the generator output. Disconnect the leads at the regulator and connect a 12-volt battery capable of supplying one amp to the leads. Check to make sure that the battery is connected to the leads with the correct polarity. With no load on the generator, (main breakers open) run the generator at rated speed. Measure generator output voltage. Shut the generator down. Compare the voltage reading with

design value, if they match the regulator is functioning properly (implement this procedure in accordance with manufacturers' recommendations).

*d. Load test.* This test will determine whether a problem with the sequence of the loading of the generator exists. With no load on the generator, (main breaker open) run the generator at rated speed. Gradually add load as sequenced. Standard procedures for commercial, routine and acceptance tests for determination of speed- governing performance characteristics of internal combustion engine-generator units can be found in ASME Power Test Codes (PTC) 26.

*e. Operation of multiple generators in parallel.* When operating multiple generators in parallel the operators must be aware of their operating sequence. For a system with three generators in parallel the operating sequence could be generator one then two then three or, two then one or three or, either one or two or three. A way to identify the scheme of a system is to functionally test the system by removing one generator from the system and verifying that the system operates. For example, when operating three generators in parallel, where two are normally operating and one is considered the backup generator the circuitry could be such that the first generator always acts as the starting generator and when it is up to speed, the second generator will synchronize to the first and following this, the third generator will synchronize to the second (one then two then three). In this arrangement if the first generator does not come up to speed (or is taken out of service), the second generator will not go on-line and subsequently neither will the third or, if the first generator does come up to speed but the second generator is down for service, the third will not go on-line since it is dependent on the third. A scheme where the first generator is the staring generator and either generator two or three synchronize to it is preferable over the first scheme since the probability of a second generator coming on-line is greater however you still stand the risk of the staring generator failing and thus halting the system. A preferred scheme is one where any of the three generators will perform as a starting generator and either of the remaining generators will synchronize to the generator on-line (one or two or three).

*f. Speed control checks.* When the alternating current generator sets are in parallel, load division between units is entirely controlled by the speed setting of the engine governors. Increasing the speed setting of one engine will cause it to absorb more load, and other generator sets in the system will be relieved of some load. Conversely, decreasing the speed setting of one engine will cause it to decrease load. Other generator sets will absorb that load. All load can be remove from a generator by slowly decreasing the speed setting. If the speed setting is moved lower than the no load point, that generator set will absorb power from other units which will continue to drive it at synchronous speed. It is impossible to have stable parallel operation if more than one unit in the system is set for zero speed droop (isochronous) operation unless the governors are the electronic load sharing type. When two or more units are operation in parallel, the regulator must control the excitation of the alternators so they share the reactive load. Two ways are: reactive droop compensation and reactive differential (cross current) compensation. Reactive droop compensation does not require wiring interconnection between regulators. During parallel droop compensation operation, the bus voltage droops (decreases) as the reactive lagging power factor load is increased. Reactive differential (cross current) compensation requires the addition of interconnecting leads between the current transformer secondaries and allows operation in parallel without voltage droop with reactive load. Cross current compensation can only be used when all the paralleling current transformers on all the generators delivering power to the bus are in the CT secondary interconnection loop. Because of this requirement, cross current compensation operation cannot be used when a generating system is operating in parallel with the utility power grid. Utility voltage can vary enough to cause high circulating current in a paralleled generator. KVAR controllers must be used to adjust generator voltage to match utility and minimize circulating current.

## 3-10. Batteries

Although battery type varies (e.g., NiCd, Lead Acid), the acceptance criterion remains generally the same. The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. Any apparent physical damage shall be recorded. If the battery is delivered filled, it shall be inspected to verify that no electrolyte has leaked during transit. If the battery cells are not delivered filled, it is recommended that they be filled according to manufacturer's recommendations before installation on racks. The individual cell condition check shall include visual inspection of cell integrity investigating evidence of corrosion at terminals, connections, racks, or cabinet. The general appearance and cleanliness of the battery, the battery rack or cabinet and battery area including accessibility shall be observed. The cells shall be checked for cracks in cell or leakage of electrolyte as well as the integrity of the cover. Electrolyte should be added to any cell in which the electrolyte level is below the top of the plates. Before installation, the voltage of each cell shall be measured. The voltage measured should be equal to or less than 0.05 V below the manufacturers open circuit voltage. If it is not, the manufacturer shall be contacted to determine the next course of action. The cell polarity for positive to negative connections shall be checked. The battery shall be assembled as shown on drawings. Each battery cell is then checked to ensure the electrolyte level is at the maximum level. The interconnection of the battery cells shall be checked for polarity. The connector bolts shall be checked to ensure that they have been tightened to the manufacturers recommended torque values. The cell internal ohmic values and the intercell connection resistances shall be then measured. This is accomplished by applying a load across the battery and measuring the step change in voltage and current for each cell taken between the positive and negative terminal posts of adjacent cells as well as the battery as a whole. The ohmic value is the change in voltage divided by the change in current. The resistance values for each cell shall then be averaged and any interconnection that varies more than 10% or 5 $\mu\Omega$ over the average shall be remade and then rechecked for its resistance value. These values shall become baseline values for comparison in future tests. The presence of flame arresters, adequacy of battery support racks, mounting, anchorage, grounding, and clearances, ventilation of battery room enclosure, and existence of suitable eyewash equipment shall be verified. After completion of the above inspections the battery is ready to be connected to the charger. After charging, the following should be measured: each cell voltage and total battery voltage with charger in float mode of operation; ripple current; specific gravity; electrolyte temperature; electrolyte fill level; overall float voltage measured at the battery terminals; charger output current and voltage; ambient temperature; condition of ventilation and monitoring equipment; and temperature of the negative terminal of each cell of the battery. When the battery is charged, use a voltmeter to check the polarity of the series connections. The total voltage shall be measured both across the battery and between adjacent cells and then shall be compared to the specified voltage. The total voltage should approximately be the resultant of the quantity of cells multiplied by the typical cell voltage. A variation is an indication that the battery may be improperly assembled.

*a. Discharge test.* The values for discharge time and end point voltage should be selected from the battery manufacturer's published ratings and the values used for the acceptance test should be approximately the same as that of the intended application. The discharge rate should be at a constant current or constant power load equal to the selected manufacturer's rating of the battery. The charging method used as the basis for the published data is an important factor. For a stationary float application, data based on prolonged constant potential charging should be used. If constant current charging has been used to establish the published data, appropriate float charging correction factors should be obtained from the manufacturer. Note that the test discharge current is equal to the rated discharge current divided by the temperature correction factor for the initial electrolyte temperature. Set up a load and the necessary instrumentation to maintain the test discharge rate determined in above. Disconnect the charging source, connect the load to the battery, start the timing, and continue to maintain the selected discharge rate. If the charging source cannot be disconnected, the current being drawn by the load has to

be increased to compensate for the current being supplied by the charging source to the battery. Read and record the individual cell voltages and the battery terminal voltage. The readings should be taken while the load is applied at the beginning and at the completion of the test and at specified intervals. There should be a minimum of three sets of readings. Individual cell voltage readings should be taken between respective posts of like polarity of adjacent cells so as to include the voltage drop of the intercell connectors. Maintain the discharge rate and record the elapsed time at the point when the battery terminal voltage decreases to a value equal to the minimum average voltage per cell as specified by the design of the installation times the number of cells.

*b. Capacity check.* The capacity of the battery is checked using the following equation:

$$\text{Percent Capacity at the test rate at 25°C (77°F)} = (t_a / t_s) \times 100$$

Where:

$t_a$ is the actual time of the test to specified terminal voltage as corrected for temperatures
$t_s$ is the rated time to specified terminal voltage

## 3-11. Battery chargers

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. A visual inspection should be performed to verify the completeness of the equipment, correctness of installations, supports, grounding, and wiring. The rating plate shall be checked to ensure that both the ac supply to the charger and the battery to be connected corresponds to the charger's parameters. Confirm that all shipping and other debris in and around the charger cabinet have been removed. Check settings of the charger and calibrate per manufacturer's manual to match the battery (float and equalizing levels). If the battery charger has been factory set, check the charger float and equalizing voltage levels against drawings and specifications. If not, set the charger float and equalizing voltage levels to those listed on drawings and specifications. Before connecting to the battery, measure the output voltage provided by the charger and record. Verify that all charger functions and alarms operate correctly. Verification that the battery is connected to the battery charger properly is extremely important. The negative wire from the negative terminal of the battery must be connected to the negative terminal of the charger. Similarly, the positive wire from the negative terminal of the battery must be connected to the positive terminal of the charger. A battery charger is an electronic device that converts ac power to dc power. The charger supplies this dc power to the battery. As with all electronic devices, this device should not be megger tested.

## 3-12. UPS systems

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment. The Static UPS System consists of the battery charger, inverter, battery, transfer switch, circuit breakers, and cables. A picture of a typical UPS systems is seen in figure 3-1. Of the UPS system, the component testing for the battery charger, battery, transfer switch, circuit breakers, and cables are described individually in this manual. The inverter is similar in construction to the charger. It converts dc power to ac power using solid state electronics. Therefore, this device should not be megger tested. The completeness of the assembly shall be confirmed. A visual inspection should be performed to verify the correctness of installations, supports, grounding, and wiring. Verify that the air inlets are not obstructed. The interconnections shall be checked against the wiring schematic to ensure the proper phasing and voltage connections. For example, both the battery charger connections to the battery and the battery to the inverter should be checked to insure that

they have the correct polarity. Measure the input voltage provided by the battery and record. Measure the output voltage and current from the inverter and record. Verify that these values correspond to the design values.

## 3-13. Cables

For commissioning of cables, the receipt inspection and testing is performed while the cable is still on the reel. The exposed sections of the cables are visually inspected for signs of physical damage, the end caps are checked for tightness. The cable types and configuration are checked for correctness against drawings and purchasing documents. Continuity tests are performed on each conductor and the shield. For power cables, insulation resistance tests are performed between each conductor and each conductor and the shield. The cable installation shall be checked against one-lines and schematics. After installation, the cables are inspected for damage, proper trained bending radius, adequate spacing for ampacity, proper installation of fireproofing, proper size, termination, and identification. Next, conductors are checked for continuity. The following tests shall be performed before the cables are energized. They are the insulation resistance (Megger) test and the dc hi pot test. For medium and high voltage shielded cables the acceptance is dependent on the dc hi pot test. A satisfactory test is the exponential decrease of current with time with a fixed dc voltage applied. Non-shielded cables are not

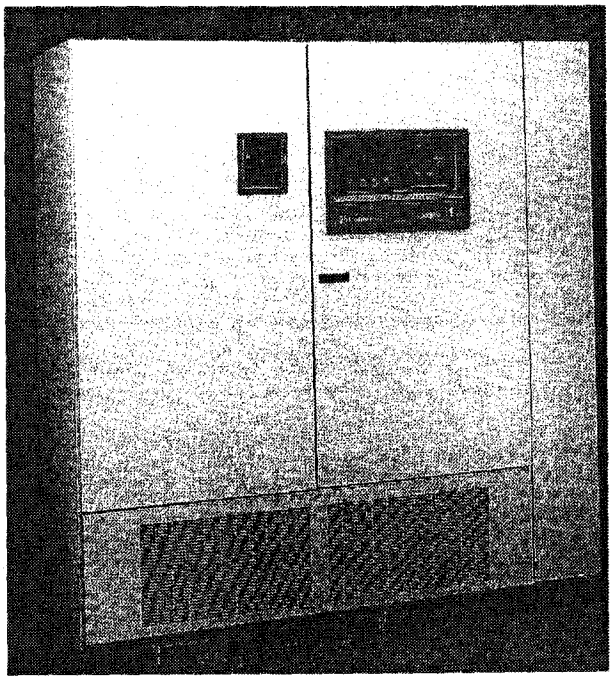

*Figure 3-1. Static UPS system 150 to 750 kVA (courtesy of Liebert)*

subject to the hi-pot test because only the sections of cable in contact with ground (such as cable tray rungs) are actually tested and therefore the test is not meaningful. Test duration should not exceed 5 minutes for non-shielded cable or 15 minutes for shielded cable. When performing a dc High-potential test on cables, all precautions and limits as specified in the applicable NEMA/ICEA (Insulated Cable Engineers Association) standard for the specific cable should be followed. Tests should be performed in accordance with ANSI/IEEE Standard 400. Test voltages shall not exceed 80 percent of cable manufacturer's factory test value or the maximum test voltage in table 3.1 below. The test procedure should be as follows and the results for each cable test shall be recorded. Test each section of cable individually with all other conductors grounded. All shields must also be grounded. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary. Precaution should be taken to insure that the maximum test voltage does not exceed the limits for terminations specified in IEEE Standard 48 or manufacturers specifications.

Reduce the conductor test potential to zero and measure residual voltage at discrete intervals. Upon the completion of the test, apply grounds for a time period adequate to drain all insulation-stored charge. When new cables are spliced to existing cables, the dc high-potential test shall be performed on the new cable prior to splicing. After test results are approved for the new cable and the splice is completed, an insulation resistance test and a shielding continuity test should be performed on the length of the new and existing cable including the splice. After a satisfactory insulation resistance test, a dc high potential test shall be performed on the cable utilizing a test voltage acceptable to owner and not exceeding 60 percent of factory test value.

*Table 3-1. Medium-voltage cables maximum field acceptance test voltages (kV, dc)*

| Insulation Type | Rated Cable Voltage | Insulation Level | Test Voltage kV (dc) |
|---|---|---|---|
| Elastomeric: Butyl and Oil Base | 5 kV | 100 % | 25 |
| | 5 kV | 133 % | 25 |
| | 15 kV | 100 % | 55 |
| | 15 kV | 133 % | 65 |
| | 25 kV | 100 % | 80 |
| Elastomeric: EPR | 5 kV | 100 % | 25 |
| | 5 kV | 133 % | 25 |
| | 8 kV | 100 % | 35 |
| | 8 kV | 133 % | 45 |
| | 15 kV | 100 % | 55 |
| | 15 kV | 133 % | 65 |
| | 25 kV | 100 % | 80 |
| | 25 kV | 133 % | 100 |
| | 28 kV | 100 % | 85 |
| | 35 kV | 100 % | 100 |
| Polyethylene | 5 kV | 100 % | 25 |
| | 5 kV | 133 % | 25 |
| | 8 kV | 100 % | 35 |
| | 8 kV | 133 % | 45 |
| | 15 kV | 100 % | 55 |
| | 15 kV | 133 % | 65 |
| | 25 kV | 100 % | 80 |
| | 25 kV | 133 % | 100 |
| | 35 kV | 100 % | 100 |

NEMA Table 10.6

Derived from ANSI/IEEE Standard 141-1993 Table 12-9 and by factoring the applicable ICEA/NEMA Standards.

NOTE: AEIC CS5 and CS6, and ANSI/IEEE Standard 400 do not differentiate cables based upon insulation thickness and, consequently, list differing test voltages.

Insure that the maximum test voltage does not exceed the voltage limits for potheads and terminators specified in IEEE Std. 48 (IEEE Standard Test Procedures and Requirements for High-Voltage AC Cable Terminations) or for molded rubber terminations specified in IEEE Std. 386 (IEEE Standard for Separable Insulated Connector Systems for Power Distribution systems Above 600 V), or manufacturer's published data.

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