1 Codes and Standards

Testing shall be performed in accordance with the applicable standards: (Note - some but not all applicable specific standards are listed below as a convenience.)

American National Standard Institute (ANSI)

C2	National Electric Safety Code.
C12	Electricity Metering, Code for.
C37	Circuit Breakers, Switchgear, Relays, Substations, and Fuses, Guides and Standards for.
C57	Distribution, Power, and Regulating Transformers.
C62	Surge Protection.
Std 43	Testing Insulation Resistance of Rotating Machines, IEEE Recommended Practice for.
Std 48	High-Voltage AC Cable Termination, IEEE Standard Test Procedures and Requirements for.
Std 81	Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System, IEEE Guide for.
Std 120	Electric Measurements in Power Circuits, Master Test Guide for.
Std 400	Making High-Direct-Voltage Tests on Power Cables in the Field, IEEE Guide for.
Std 450	Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations, IEEE Recommended Practice for.
Std 525	Installation and Design of Cable Systems in Substations, Guide for.
Std 1106	Maintenance, Testing, and Replacement of Nickel-Cadmium Storage Batteries for Generating Stations and Substations, IEEE Recommended Practice for.

American Society For Testing and Materials (ASTM).

D877	Dielectric Breakdown Voltage of Liquids Using Disk Electrodes, Methods of Test for.
D923	Sampling Electrical Insulating Liquids, Test Method for.
D1500	ASTM Color of Petroleum Products, Test Method for.
D1816	Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes, Methods of Test for.
D3284	Combustible Gases in Electrical Apparatus in the Field, Test Method for.

Insulated Power Cable Engineers Association (ICEA).

S-19-81	Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.
S-66-524	Cross-linked Thermosetting Polyethylene--Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

National Fire Protection Association (NFPA)

70	National Electrical Code (NEC.)
70B	Electric Equipment Maintenance, Recommended Practice for.
70E	Electrical Safety Requirements for Employee Workplaces.
101	Life Safety Code.

International Electrical Testing Association (NETA), Acceptance Testing Specification, http://www.netaworld.org.

National Electric Manufacturer's Association (NEMA).

Occupational Safety and Health Administration (OSHA).

EEI - Handbook for Electricity Metering.

2 Tests

For the following sections, the term "function" or "function testing" means applying the appropriate inputs (voltage, current, pressure, temperature, etc.) to a device, and verifying all required responses or outputs. Testing should be done on the specified equipment after it is fully assembled and installed at its permanent location. The types of tests covered by this criteria document include, but are not be limited to the following:

In general, all equipment will require the following:

(1) Inspection - Visual and mechanical inspections shall be performed.
(2) Verify the nameplate data against the design criteria and the "Bill of Materials".
(3) Check that there are no broken or cracked parts or other physical damage. Check that screws are tight. This includes relays, synchronizers, cases, and covers.
(4) Check devices for moisture or damage from moisture and foreign materials that could inhibit the proper operation and functioning of the devices.
(5) Check for proper contact alignment and travel, disc rotation for freedom of movement, target operation, etc. Adjust mechanical alignments according to the manufacturer's specification.

3 Individual Equipment Testing

3.01 Power Transformers

1. Physical Testing

(1) Dew point test the atmosphere inside the transformer main-tank at time of arrival. Also check pressure/vacuum gauge for proper shipping pressurization.
(2) Core to ground Megger® test. This should be also be completed prior to offloading of transformer. This should be completed on the main core as well as the PA core if present.
(3) Power factor test Bushing & Arresters (before installation)
(4) Internally inspect load tap changing mechanism (**LTC**) to make sure all parts are solidly connected and are operating smoothly
(5) Internal inspection the main-tank before oil filling.
(6) Process the transformer oil and pull vacuum on the transformer to ensure no moisture remains in the transformer or the oil (oil processing unit).
(7) Insulating oil:
   a. Visual inspection.
   b. Dielectric test per ASTM D877 during installation and ASTM D1816 for final acceptance prior to energization.
   c. Verify proper oil level(s) per manufacture's instructions.
   d. Take oil samples (Main Tank and LTC) for laboratory tests (power factor, gas-in-oil, moisture, D1816 dielectric, interfacial tension, acidity, and color).
(8) Verify nitrogen blanket pressure.
(9) Check bushing oil level per manufacture's recommendation.
(10) Measure overall power factor with NLTC on nameplate nominal tap and LTC on neutral tap.
(11) Measure power factor of bushings after installation.
(12) Megger® Test windings.

(13) Measure transformer turns ratio (**TTR**) with the following tap settings:
   a. Test each NLTC tap with the LTC in the neutral position
   b. Test each LTC tap (16R-1L) with NLTC on the nameplate nominal tap
(14) Measure exciting current with the following tap settings:
   a. Test each NLTC tap with the LTC in the neutral position
   b. Test each LTC tap (16R-1L) with NLTC on the nameplate nominal tap
(15) Measure winding resistance (Double Bridge) with the following tap settings:
   a. Each HV Winding -Test each NLTC tap with the LTC in the neutral position
   b. Each LV Winding -Test each LTC tap (16R-1L) with NLTC on the nameplate nominal tap

2. Control Testing

(1) Local tests done at the transformer
(2) Perform current transformer (CT) Tests
(3) Function heater control circuit (verify heater watt consumption)
(4) Check calibration of temperature gauges
(5) Using a temperature calibrator to check fan control contacts to term blocks (should be set to factory recommendations)
(6) Check the gauges for accuracy (should be +/- 5 degrees C)
(7) Check mA output of temperature transducer at term block
(8) Put current into winding temp gauge and verify that the reading increases
(9) Local function test of fan and pump controls.
(10) Local function test LTC control
(11) Function local/remote, auto/manual "mode" switches
(12) Apply settings to "90" device and verify settings with test set
(13) Check alarms to terminal blocks

Wire check AC circuit

(14) Set/test relaying
(15) Function control circuits (operate lockouts, sudden press, etc.) use current to trip relays
(16) Perform system test of LTC control including paralleling with other transformer(s)
(17) Jumper alarms at the transformer terminal blocks previously tested to test annunciator and RTU/PLC inputs
(18) Check controls to control house including tap position indicator (**TPI**)
(19) Test and document energy management system (**EMS**) control, alarms and status
(20) Check current draw (and rotation) of pumps and fans with clamp-on CT's

3.02 Circuit Breakers

1. Physical Testing

(1) Fill with gas (SF-6 breakers only) and have SF-6 tested as required.
(2) Perform oil quality tests (as defined under Transformer) (for oil breakers only)
(3) Connect operating Linkage (for independent pole breakers)
(4) Perform Hi-Pot vacuum bottles and check measurements (vacuum breakers only)
(5) Perform visual and operational check of mechanism
(6) Perform timing and velocity tests
(7) Perform power factor test on individual bushings and overall power factor
(8) Sniff/soap for leaks on gas breakers
(9) Measure contact resistance

2. Control Testing

(1) Perform current transformer (CT) Tests

(2) Local checks at the breaker:
   a. Check function of heater circuit.
   b. Check function of controls (trip, close, block trip/close, dual trip coil, anti-pump, etc.)
   c. Check alarms to terminal blocks
   d. Check labeling of fuses, switches and relays
   e. Check calibration of relays at breaker
(3) Wire check AC circuit
(4) Calibrate relaying
   a. All associated breaker failure relays
   b. All associated sync-check and voltage monitoring relays
   c. All associated reclosing relays
   d. Any synchronous pole operation controls
   e. All associated PLC (programmable logic controller) alarm and control schemes

3.03 Metal-clad Circuit Breakers And Switchgear

1. Physical Testing

(1) Perform instrument transformer testing.
(2) Perform power factor testing of arresters, roof bushings, bus work, VTs, and house power transformer.
(3) Perform motor testing.
(4) Equipment ground verification.
(5) Perform high potential testing.
(6) Perform relay testing.
(7) Perform Ducter® testing.
(8) Perform automatic bus throw-over function and calibration testing.
(9) Coordinate, as needed, feeder exit cable testing.
(10) Perform functional and operational testing.
(11) Verify interlocks and safety features.

2. Control Testing

(1) Perform alarm sensor testing.
(2) Perform control and instrument switch testing.
(3) Perform instrument calibration.

3.04 Circuit Switchers and Motor Operated Disconnect Switches

1. Physical Testing

(1) Verify pole synchronism. Switches should be adjusted to manufacturer tolerances.
(2) For Circuit Switcher and LineRupter® type devices, perform insulation resistance tests on each pole in accordance with the manufacturer's recommendations.
(3) Measure the contact resistance across each closed switchblade.
(4) High-Pot vacuum bottles
(5) Power factor test on individual bushings and overall power factor
(6) Check and align switch/fuse combinations
(7) Verify that expulsion limiting devices are present on all holders having expulsion type elements.
(8) All problems shall be resolved and all adjustments completed prior to driving the piercing bolts.
(9) For Circuit Switchers, LineRupters®, and similar devices, check the timing of the shunt trips and the mechanical trips on the attachments.

2. Control Testing (MOD's and Circuit Switchers Only)

(1) Check function of heater circuit.
(2) Check local function of limit switches.
(3) Verify proper cam positioning.
(4) Check local function of interlocks.
(5) Check function of controls from control house.
(6) Test and document EMS control and status

3.05 Regulators – Three Phase Or Single Phase

1. Physical Testing

(1) Perform overall power factor test
(2) Verify transformer turns ratio (**TTR**) - Go through all taps

2. Control Testing

(1) Check for proper orientation of regulator and voltage sensing transformer.
(2) Check VT ratio
(3) Test load drop compensation CT (ratio and polarity only)
(4) Verify set-point, bandwidth, time delay, and compensation
(5) Test for proper voltage control once regulator is placed in service

3.06 Capacitor Banks

1. Physical Testing

(1) Measure and record capacitance of strings/series groups with capacitance meter.
(2) Verify equipment is properly grounded

2. Control Testing

(1) Perform Current Transformer (CT) Tests
(2) Perform VT testing
(3) Perform capacitance value check - by voltage method (fuseless only) verify equal voltage distribution across each can
(4) Check synchronous breaker closing - verify connections & match phases (Sync close unit gets functionally checked during initial energization)
(5) Perform wire check of AC circuits
(6) Calibrate relaying
(7) Verify metering calibration
(8) Verify function of control circuits
(9) Test alarms to annunciator and to RTU/PLC (remote terminal unit) inputs
(10) Test and document EMS analog, control, alarms and status
(11) Monitor energization and sync close learning wave forms

3.07 Transmission Line Relaying

1. Control Testing

(1) Wire check AC circuits
(2) Check Line VTs
(3) Perform manufacturer's acceptance tests for all line relays
(4) Calibrate relaying, and verify settings for all line relays
(5) Set up pilot relaying and transfer trip equipment common to all piloted systems
   a. Apply settings
   b. Perform "back to back" local function tests

c. Perform "end to end" piloted relaying and transfer trip tests
d. Record installed signal receive levels
e. Check alarms to annunciator and EMS
f. Fiber

(6) Tone equipment
(7) Carrier equipment
(8) Verify metering calibration
(9) Function relaying control circuits
(10) Perform tuning of carrier equipment on ungrounded line
(11) Test and document EMS analog, control, alarms and status

3.08 PLC & HMI Equipment Setup

(Software programs are tested as part of the control system testing)

1. MODBUS® Plus and Equivalents

(1) Label all MODBUS® plus equip with their address – verify no duplication of addresses
(2) Apply MODBUS® Plus addresses to equipment (power must be cycled on device for address changes to take affect)
(3) Lift all MODBUS® plus connectors and wire check entire MODBUS® plus network at each device. The physical end connector must contain a 120 ohm terminating resistor (60 ohm between pair and open to shield).

2. PLC (Programmable Logic Controller)

(1) Load PLC program
(2) Verify terminal block switches are connected to the proper I/O and labeled to the standard.
(3) Jumper or force outputs to check all hardware shown on the schematic
(4) Check inputs by watching LEDs or by watching data screen on computer
(5) Check for loss of communication, low battery, and processor not in RUN , give "PLC failure" alarm
(6) Document field program changes on the paper copy and save on hard drive
(7) Verify transducer calibration
(8) Check analog circuit calibration into PLC
(9) Apply software configuration jumpers and register values in the PLC program as shown on relay test sheets
(10) Perform functional tests based on logic documentation after hardware tests are complete
(11) Save PLC program to disk and leave floppy and as left reprinted hardcopy on site

3. HMI (Human Machine Interface) Computer

(1) Set up and configure HMI (computer) and associated hardware
(2) Load HMI software
(3) Test all displays for functionality and accuracy
(4) Test alarm points
(5) Incorporate testing with PLC functional testing
(6) Save copy of HMI file and leave floppy on site

4. Data Concentrator

(1) Load settings for data concentrator
(2) Check for proper data gathering

3.09 SCADA Systems and Annunciators

1. SCADA tests

(1) Set-up Remote Terminal Unit (**RTU**) equipment

(2) Function test all control, indication, alarm, and analog points in the RTU, to and from the EMS. Verify SCADA descriptions match inputs.

2. Traditional Annunciator tests

(1) Check all points including spares along to verify operation of lights, bells, cutoffs, and resets.

(2) Verify labeling matches print and is to standard

3. Programmable display panel tests

(1) Load configuration software

(2) Verify labels are correct in both the schematic and settings spreadsheet.

(3) Save final configuration to disk to leave on site.

3.10 Substation Batteries & Chargers

1. Physical Testing

(1) Clean, lubricate and install inter-cell connectors.

(2) Torque inter-cell connectors to manufacturer's specifications

(3) Measure and record resistance of inter-cell connectors

(4) Test DC voltage (float & equalize)

(5) Measure temperature and specific gravity of each cell.

(6) Perform a battery discharge test per IEEE 450 (if required)

2. Control Testing

(1) Check loss of AC alarm

(2) Calibrate battery monitoring relay

(3) Test alarms to annunciator and to RTU/PLC inputs

(4) Test and document EMS alarms

(5) Verify DC lighting system (if required)

(6) Verify correct coordination of charger with vent fan operation (if required)

3.11 Ground Grid

1. Ground Grid Resistance Tests

(1) Perform a substation ground grid resistance to remote earth test using the three-point method.

(2) Record the results, create a site sketch, and notify the Xcel Energy of the results.

(3) For new substations, where practical, one set of tests shall be performed prior to the connection of the transmission line statics and the distribution feeder neutrals to the station ground grid and one set shall be performed after connection of the statics and the neutrals.

(4) For additions to existing substations, one test shall be performed with the statics and the neutrals connected.

2. Equipment Ground Connection Tests

(1) Utilizing the two-point method, measure between each piece of equipment and a known low impedance ground grid node.

(2) Any ground connection exhibiting greater than 0.02 ohms to the grid shall be reworked. All other exposed metal items such as handrails shall measure less than 0.05 ohms to ground.

3.12 Power Cable (If Required)

High-voltage power cable shall be tested in accordance with ICEA S-19-81 6.22.8, and S-66-524 6.14.7, "Voltage Tests After Installation", or equivalent.

3.13 Auxiliary And Miscellaneous Equipment

1. Telephone equipment (see transmission line relaying for protective communication equipment)

(1) Set-up and test telephone protection equipment (POSITRON®/SNC®)

(2) Phone line tests

a. Perform and document end to end tone circuit sweeps

b. Verify circuit is identified with phone company reference and a functional description of what Xcel system it is used for.

c. Check that loop-back is properly identified with circuit number and Xcel description

d. Check that loop-back is DC powered or is passive

e. Verify that protected and unprotected telephone wiring is properly separated in phone cabinet

(3) Set up and test phone bridge when used

(4) Telephone switch

a. Function test telephone access control switch (local and EMS)

b. Set up and test modem and port switch (RFL-9660, SEL-2020/2030) configuration

c. Test communication to each port used

d. Telecommunications SPABX® (Smart Switch®), modem, and similar devices

2. Fiber optic (see transmission line relaying for protective communication equipment)

(1) Document fiber optic circuit dB loss (for short runs) tests

(2) Document OTDR tests for long runs

3. Station Aux./ Transfer Switches/Load Centers

(1) Check all circuit connections immediately prior to energization

(2) Energize equipment one stage, section, circuit, or piece at a time to minimize the damage in the event of an equipment failure and to aid in locating trouble areas.

(3) Put settings on transfer switch, verify proper voltage magnitudes, current magnitudes, phasing, and correct operation during energizing

(4) Check all interlocks and verify the correct operation of keyed interlocks (Kirk® key). (If required)

(5) Equipment ground verification.

(6) All measurements and tests shall be recorded.

(7) Load centers

a. Verify correct labeling and fusing of load center circuits

b. Check or verify that construction has functionally checked the labeling of the load center loads

4. Load shedding system

(1) Function Test

5. Self contained reclosers

(1) Apply settings per relay test sheet

(2) Apply primary current and record test times
(3) Prove lockout switch
(4) Prove reclosing functions
(5) Check shunt trip device (when used)

6. Misc. equipment (if required)

(1) Control & instrument switches
(2) Verify operation and design function of and proper operation sequence of all devices.
(3) Check control house temp alarm (check to annunciator and EMS)
(4) Check control heater and vent fan controls and proper labeling
(5) Verify time stamp and time reference systems.
(6) Doble® surge arresters, bus work, free standing CT's, coupling capacitors (CCs), VTs, CVTs, and CCVTs, and air core reactors.
(7) Verify functionality of HVAC systems.
(8) Verify functionality of security intrusion alarm systems.
(9) Verify functionality of fire alarm systems.
(10) Verify functionality of switchyard lighting control system.
(11) Verify functionality of irrigation well control system.

3.14 Motors

(1) Verify that the correct voltage taps are in use.
(2) Verify that the proper direction of rotation is present on the three-phase motors.
(3) Verify that the motor is properly lubricated.

3.15 Phasing and Synchronizing

(1) Maintain the correct phasing on all circuits and buses. The substation buses and connections shall have the phasing as shown on the drawings. All bus work shall be physically checked for phasing and verified to be correct and as shown on both the station general arrangement drawings, the bus plans, the three line drawings, and the relaying schematics.
(2) Perform phasing tests on all circuits that can be energized from two or more sources. All voltage and current phase angles shall be referenced to the same reference quantity for all readings on a specific scheme. The phasing shall be checked with phasing voltage probes where practical.
(3) Test operation of the syncroscope and lights on the various control boards or the synchronizer and/or synchronism check device LEDs by checking the indication when comparing two potentials energized from the same source. Check and record all phase angles on all phases for the permanent record.
(4) After the syncroscopes have been checked, test correctness of the synchronizing connections and the synchronism check relays for the individual lines by operation of their respective synchronizing switches and the alternate application and removal of the individual potential sources to the syncroscope and relays. Verify that Xcel Energy's delta-wye phase shift and phase rotation conventions are met.
(5) Phasing and synchronizing tests shall be made with Xcel Energy present.

3.16 Corona Testing

(1) For substations operating at or above 230 kV and for any substation that is operating with reduced phase-to-ground or reduced phase-to-phase clearances, that substation shall be tested for corona by use of "night vision" equipment.

(2) Other means such as ultra-sonic equipment and time exposure photography shall also be used as needed to locate the sources of excess corona. The tester shall inspect all high voltage equipment, buses, leads, etc. for corona.

3.17 Fault Recording Systems

(1) Verify and/or configure equipment to the manufacturer's specifications and Xcel Energy provided specifications.

(2) Phase and check all inputs for proper levels and indication.

(3) Test data access and polling functions.

(4) Coordinate with Xcel Energy to test remote data retrieval functions.

(5) Document all as-left configurations and return to Xcel Energy.

3.18 Auto-Reclose Function

Reclosing is usually applied to all distribution feeders and transmission line terminations. This function may be performed by a separate relay or be a function within another relay (usually microprocessor based).

(1) Verify and test all control switches, SCADA control paths, and 86 lockout permissive contacts in the reclose circuits.

(2) Verify and test reclose initiate paths by applying a test fault to the appropriate protective relays.

(3) Verify and test reclose cancel (reclose block) paths and reclose cycle timing by applying a test fault to the appropriate protective relays. Reclosing times and reclosing details will be provided by Xcel Energy.

(4) Verify & test all reclosing conditions

3.19 Substation Bus Protection

(1) Perform current transformer (CT) Tests

(2) Wire check AC circuit

(3) Check bus VT's

(4) Perform relay setting/calibrate relaying

(5) Verify metering calibration

(6) Check digital meter with analog mA output

(7) Multifunction digital transducer/meter with MODBUS® plus output

(8) Test function of control circuits

(9) Perform bus differential upset test (if required)

(10) Test alarms to annunciator and to RTU/PLC inputs

(11) Test and document EMS analog, control, alarms and status

3.20 Current Transformers

1. Control Tests

(1) Check that high voltage connections of transformers and breakers match the scheme

(2) Verify high voltage phasing is correct

(3) Verify phasing is correct
(4) Verify that all documentation including, CT nameplates, M&R, relay test sheets, and schematics match (polarity marks and ratios).
(5) All CT's used for revenue metering or interchange metering must have ratio correction test curves and phase angle correction test curves. All CTS in this service, which do not have these test curves available from the manufacturer or CT supplier, shall be tested and curves produced as outlined in the EEI "Handbook for Electricity Metering". Normally the ratio correction and phase angle correction curves are specified as part of the purchase specification and will be provided from the supplier.
(6) Make sure CT connections are proper to give the desired protection.
(7) Verify that actual tap connected will give the ratio on the scheme
(8) Verify ratios and connections are correct for transformer differential relaying systems.
(9) Fill out CT documentation
   a. Polarity check – relative to polarity marks (physical), the bridging direction (electrical) and the drawings
   b. Ratio/Taps check – all taps
   c. Secondary injection (excitation)
   d. Test and record CT voltage saturation
(10) Wire checking – See Wire Checking
(11) Perform Meg Ohm test (500V scale) to ground
(12) Make sure bushings are labeled with phase and bushing number

3.21 Voltage Transformers & Coupling Capacitor Voltage Transformers

1. VT and CCVT Physical Testing

(1) Perform power factor tests

2. VT and CCVT Control Testing

(1) Verify that actual tap connected will give the ratio on the scheme
(2) Make sure VT nameplate, relay test sheets, and schematics match (polarity and ratios).
(3) Perform wiring checks on CCVT
(4) Perform ratio and polarity checks on wound VTs and distribution transformers used for metering or relaying
(5) Wire checking

3.22 Wire Checking

1. (CT and VT circuits only)

(1) Perform continuity check of all current shorting switches
(2) Perform continuity check of all CT wiring
   a. Inject currents at the source of each current transformer string and check the string at each device with a clamp-on ammeter or current probe to verify that all current transformer strings are connected in accordance with schematics
   b. Simulate the actual load current and fault current operation of the substation electrical systems by injecting appropriate currents into the CT strings to check the protective relay operation, the CT circuits, the meters, and the instruments.
(3) Perform continuity check of all VT wiring (if required)
   a. Pull the fuses from CVT. CCVT, PD, or VT junction boxes and apply the proper phase-to-phase and phase-to-ground voltages to the load side of the fuse blocks. Check for the

proper voltages at all relays, instruments, switches, etc. to verify that the voltage circuit is connected in accordance with the schematics.

(4) Verify tagging/labeling to standards

(5) Verify proper fuse sizing of voltage circuits

(6) Visually and mechanically (pull on wire) inspect terminations

(7) Verify that all VT and CT circuits have one and only one ground (exception is for power/metering VT which are grounded at both transformer and at the first panel).

3.23 Infrared Temperature Survey

All infrared surveys shall be performed after the equipment has been loaded.

(1) Survey all substation bus, conductors, and connections.

(2) Survey all oil filled tanks (transformers, tap changers, oil circuit breakers, etc.).

(3) Survey all surge arresters, CVTs, and CCVTs.

(4) Survey all equipment including metal-clad switchgear.

(5) Survey all high voltage power cable connections.

(6) Survey all circuit breakers, reclosers, and switches.

(7) The infrared tests will include scanning all electrical connection points including terminal points and electrical contactors.

(8) Inspect transformers for blocked radiators or any localized heating.

(9) Tests will be performed with the equipment in-service or operating.

(10) A test report will be submitted on all tests including pictures of any problems or questionable areas. A questionable area is defined as an area where the temperature is 10 ^{o}C greater than its surrounding area. The problem area shall be corrected by the Contractor and the area re-tested.

3.24 AC Circuits

(1) Verify proper voltage rating of equipment before fusing up

(2) Verify correct labeling and breaker size

(3) Verify correct circuit feeds the equipment and that the scheme circuit number is correct

(4) Verify that "wild leg" is not used on 120 V circuits.

3.25 Dc Circuits

(1) Verify proper voltage rating of equipment before fusing up

(2) Verify correct labeling and fuse sizes as per the drawings

(3) Verify that the scheme reflects the correct circuit number

(4) Check for proper polarity at device

(5) If possible, remove or turn off equipment power supplies before initial Energization then check polarity before turning on

(6) Test for shorts, grounds and back-fed DC (cross-coupled voltage test) before initially installing DC fuses for the first time.

(7) After each new circuit is fused up, check the battery for grounds

(8) Make sure all unused fuse blocks have wooden dowels inserted

3.26 Metering

(1) Check calibration of all metering including analog transducers, analog meters, and digital meters

(2) Apply standard configuration to programmable meters

(3) Using a calibration standard, check the accuracy of the watt-hour meters and the pulse initiators (KYZ) according to ANSI C12 and as directed by the manufacturer.
(4) Check and record the output at 0 percent and one non-zero point.

3.27 Relay Setting/Testing

(1) Get project relay test sheets from Xcel Energy or Producer.
(2) Verify proper labeling of relay to match drawings. (Do not place labels on the removable covers of relays but rather on the panel or the relay itself)
(3) Make sure that removable relays are tagged as well as the panel.
(4) Relay testing
   a. Perform acceptance tests in accordance with the manufacturer's instruction books.
   b. Verify operation of all light emitting diode indicators on relays containing such features.
   c. Set the contrast for liquid crystal display read-outs.
   d. Check the electrical and mechanical continuity of all taps, jumpers, etc.
   e. Verify that the electro-mechanical relay devices function at all tap settings (i.e., operable, not calibrated). Verify that the electro-mechanical relay devices are calibrated within the manufacturer's tolerance specifications at the relay settings provided by the Engineer.
   f. Install settings on relays
   g. Test all relays to the values provided.
   h. Electro-mechanical relays shall be tested in a case. Cases shall not be pulled from the relay switchboards or unwired for this purpose. Relays can be tested in the case while mounted on the relay panel or in spare cases used for bench testing.
   i. Solid state types of relays that are in a draw-out style case shall be tested as outlined above.
   j. Microprocessor and solid state types of relays that cannot be removed from a case shall be tested, prior to being mounted or wired on the switchboard, by the use of test stabs or plugs into their access points.
   k. If testing is required after the relay is wired, the relay may be unwired and tested using the relay's access termination points. However, if a relay is unwired, all circuits disrupted shall be retested to verify correct termination and operation.
   l. All protective relay operating tolerances shall be set, at a maximum, to manufacturer's specification or +/- 5%, whichever is less.
   m. Verify all of the inputs and outputs of the relay device for the correct internal functioning. Verify that the correct targets drop/show for each output.
   n. Relays with no field settings, such as lockout and auxiliary tripping relays, shall be randomly tested for pickup and dropout voltages and times. Measure the coil impedance if required. Document and sign working copy of relay test sheets after calibration and logic testing are complete.
(5) Label instruction book with date installed and equipment covered and write "substation copy" on the instruction book
(6) Put label on back of relay with installed date and list communication parameters (cable, special interface software, passwords, etc.) if required
(7) Reprint final version of relay test sheets and upload the electronic files.

3.28 Voltage Transformer Throwover Schemes

The protective relaying VT source throwover scheme shall be tested as follows:

(1) Test the 83V relays on each source.

(2) The secondary fuse block fuses shall be pulled to isolate the voltage transformers. Inject voltages on the secondary side of the bus VT fuse blocks. Verify that the proper relays receive the appropriate voltages for the 83V relay in the "Normal" and "Alternate" positions. Repeat this test for the alternate feed condition.

(3) Actuate the 83V relays by using the push button and the appropriate bus lockouts and verify that the lockout relay initiates throwover to the alternate source.

4 Demonstration Testing

(1) Simulate real world tests with relaying systems by using AC quantities to operate the protective relays and then using the trip output to turn off the test set.

(2) Trip and verify reclosing of breakers

(3) Check MOD sectionalizing.

(4) Trip lockouts from relays

(5) Place all equipment in the condition it was found in at the beginning of the outage and place new equipment in service

5 Post-Energization Testing And Review

(1) Review drawings to make sure all testing is documented or punch listed and that loose ends have been addressed.

(2) Check all relaying is on and in service.

(3) Make sure all equipment and control switches are in the position that they were switched out as

(4) Close all blocking bar switches/lockout switches if required

(5) Check all panel grounds are landed.

(6) Verify all unused CT's are shorted and grounded.

(7) Verify all alarms and EMS points are in service.

(8) Check for battery grounds.

(9) Verify that switching request allows for parallel sources during load check of differential relaying before feeding radially.

(10) Load check & in service checks.

a. Load check all new/modified CT circuits

Differential Relays: Compare restraint to operating quantities to ensure correct configuration. It is especially important on differential relays to verify correct operation under load when all inputs are energized.

Distance Relays: Measure the line power flow as seen by the relay inputs, and compare to line metered values to verify proper polarity and tap settings.

Overcurrent Relays: Compare input currents with other metered values, and verify polarity where applicable.

b. Phase check new/modified voltage circuits, verify all fuses are good.

c. Verify metering locally and at EMS.

d. Check rotation of transformer pumps and fans.

e. Check load on transformer pumps/fans with clamp on meter.
f. Check for proper operation of transformer/regulator LTC and paralleling operation.
g. Check for proper operation of transformer differential relaying.
h. Verify all relays have the proper voltages and current quantities present.

(11) Do in service adjustments of carrier tuners & receivers then record signal levels.3

(12) Take transformer insulating oil samples for analysis one day, one week, and one month following energization.

(13) Infrared heat scan test major equipment (transformers, circuit breakers, switches, bus, etc.) following energization.

5.01 Limitations on Post-Energization Load Testing

When conducting phase-out testing of the current circuits to the current restraint transformer differential or bus differential relay schemes, sufficient load must be available to make a definitive judgement to determine whether the scheme may be released for service. A significant phase-angle measurement error is possible if the circuit loading is 0.1-ampere secondary or less. If this condition exists, the relay scheme shall remain in service until adequate load is available to properly test the relay scheme later. Measurements of the operating/restraint circuit of the differential device shall be made and compared to the manufacturer's specification to verify the proper operating margin and setting of the devices.

For other relays, such as overcurrent relays, distance relays etc., the relay schemes shall be placed in-service even if inadequate load current is present for proper phase-out. Once adequate current is available, these relay schemes shall be retested for proper phase-out.

Any future testing required after 30 days (from when all buses have been energized) shall be handled by Xcel Energy if due to a delay on the part of Xcel Energy to provide adequate load for proper phase-out of current circuits.

6 Project Documentation And Clean Up

(1) Provide necessary drawings to Xcel Energy

(2) Provide necessary and relay test sheets/documentation to Xcel Energy
a. Submit forms showing relay tests performed and results
b. Put a label on the IL that says "Substation copy" with the relay name and the installed date. Multiple relays can be listed on a single IL.
c. Put a label on the instruction book for the transformer, breakers, etc. that reads "Substation copy" and list the name of equipment and the installed date. Multiple equipment can be listed on a single instruction book.

(3) PLC and HMI files
a. Send electronic copies of PLC/HMI programs to Xcel Energy
b. Get an "as left" hardcopy and floppy of the PLC programs in a binder for substations.
c. Leave a floppy copy in a trip switch holder attached to each PLC (all other PLCs).

(4) Other documentation
a. Update corrections to trip switches
b. Create list of unfinished items and send to Xcel Energy
c. Send copy of load check to Xcel Energy

d. Write reports for unresolved, unsatisfactory issues or non-project problems

(5) Misc. closeout activities

a. Check all annunciator points are turned on and not in alarm
b. Check all relay targets are reset and that all relay systems are in service
c. Check for battery grounds
d. Check that drawings and instruction books are updated and in relay cabinet or print rack
e. Verify that all EMS points are in service
f. Check that all new relays have the time and date set and event history cleared
g. Verify that remote access works to all ports on the telephone switch

Verify all fuses are installed in the panels, FT test-switch covers are on, blocking bar switches/lockout switches are in place.