33 Operations Tests

33.1 Normal operational tests

33.1.1 To determine whether an automatic transfer switch complies with 16.1.3 through 16.1.4, the switch shall be mounted in the intended manner and the secondary control circuits for the normal and alternative supplies shall be energized using separate circuits of rated voltage and frequency. Each test shall be conducted twice:

a) Once with all time delays set to their minimum value.

b) Once with time delays set at an intermediate value.

The transfer switch shall operate as intended during each test.

33.1.2 Operation on loss of supply voltage: With the transfer switch in the normal supply position, and with the secondary control circuits set to the rated value:

a) Interrupt one phase of the normal supply.

b) Restore the normal supply.

c) Repeat for each phase individually.

d) Operate the test switch.

33.1.3 Operation on reduction of supply voltage: With the transfer switch in the normal position, and with the secondary control circuits set to the rated value:

a) Lower the voltage of the normal source on all three conductors one at a time and verify the switch transfers to the alternate source at a voltage less than normal supply voltage dropout point and does not transfer at a voltage above the dropout point.

b) Raise the voltage of the normal source to the minimum normal supply voltage pickup point and verify the switch transfers to the normal source.

33.1.4 Transfer on availability of alternative voltage and frequency: With the transfer switch in the normal supply position, and with the secondary control circuits set to the rated value:

a) Test for transfer on availability of alternate voltage as follows:

1) Lower the alternate voltage to the minimum voltage setpoint.

2) Operate the test switch and verify the transfer occurs.

3) Return the transfer switch to the normal condition.

4) Lower the alternate voltage to a voltage of 10 percent less than the minimum voltage setpoint.

5) Operate the test switch and verify the transfer does not occur.

b) Test for transfer on availability of alternate frequency:

1) Lower the alternate source frequency to the minimum frequency setpoint.

2) Operate the test switch and verify the transfer occurs.

3) Return the transfer switch to the normal condition.

4) Lower the alternate source frequency to a frequency of 10 percent less than the minimum frequency setpoint.

5) Operate the test switch and verify the transfer does not occur.

33.2 Closed transition switch normal operation test

33.2.1 To determine whether an automatic transfer switch complies with 16.1.3 to 16.1.4, the switch shall be mounted in the intended manner and the secondary control circuits for the normal and alternative supplies shall be energized using separate circuits of rated voltage and frequency. Each test shall be conducted twice:

a) Once with all time delays set to their minimum value; and

b) Once with time delays set at an intermediate value.

33.2.2 Operation on loss of supply voltage: With the transfer switch connected to the normal supply, all transfers shall result in open transition operation except for (d) which shall be a closed transition transfer.

With the transfer switch in the normal supply position, and with the secondary control circuits set to the rated value:

a) Interrupt one phase of the normal supply.

b) Restore the normal supply.

c) Repeat for each phase individually.

d) Operate the test switch.

Closed transition shall not occur unless synchronized.

33.2.3 Operation on reduction of supply voltage: With the transfer switch in the normal position, and with the secondary control circuits set to the rated value, lower the voltage of the normal source on all three conductors one at a time, and verify the switch transfers open transition to the alternate source.

33.2.4 Operation on reduction of alternate frequency: With the transfer switch in the alternate supply position, and with the secondary control circuits set to the rated value:

a) Lower the alternate frequency to the minimum setpoint.

b) Operate the test switch.

33.2.5 Prevention of transfer on sources that are not synchronized: With the transfer switch in the normal supply position, and with the secondary control circuits set to the rated value but out of phase by 15 electrical degrees with respect to each other:

a) Operate the test switch.

b) Verify operation of the failure to achieve synchronization alarm, and verify the switch performs an open transition transfer.

33.2.6 Operation of the controls to prevent extended parallel of the normal and alternate source:

a) With the transfer switch connected to the normal source, set the normal and alternate source voltage and frequency to the nominal values. Prevent the normal source operator from operating (by some means such as an external shunt circuit, switch, or physically holding the operator in the closed position). Operate the test switch. Verify that the switch performs a closed transition transfer. Verify the alternate supply contacts open after the extended parallel time delay has expired.

b) With the transfer switch connected to the alternate source, set the normal and alternate source voltage and frequency to the nominal values. Prevent the alternate source operator from operating (by some means such as an external shunt circuit, switch, or physically holding the operator in the closed position). Operate the test switch. Verify that the switch performs a closed transition transfer. Verify the normal supply contacts open after the extended parallel time delay has expired.

34 Overvoltage Test

34.1 The coil of an electromagnet shall be capable of withstanding 110 percent of the rated voltage for the maximum time it is normally energized in service without damage.

34.2 To determine whether an operating coil complies with the requirement of 34.1, the coil shall be subjected to the increased voltage under operating conditions until the coil attains constant temperature.

34.3 After attaining constant temperature, the voltage shall be reduced to 85 percent of the rated voltage. The electromagnet shall operate as intended.

34.4 A coil of an electromagnet that has previously been investigated to component requirements that demonstrate compliance with these test requirements need not be subjected to the overvoltage test.

35 Undervoltage Test

35.1 This test applies only to a transfer switch that is provided with phase-voltage sensing relays incorporating a coil as the sensing means. Other than as noted in 35.2, the phase-voltage sensing relay shall comply with 35.3 through 35.6.

35.2 A phase-voltage sensing relay that has previously been investigated to component requirements that demonstrate compliance with these test requirements need not be subjected the undervoltage test.

35.3 The coil of the phase-voltage sensing relay shall be subjected to a voltage equal to 95 percent of its rated pull-in voltage for 4 hours.

35.4 Immediately after the 4 hours of operation in 35.3, the relay shall perform acceptably at its rated voltage.

35.5 The voltage shall be raised to rated voltage, and allowed to operate continuously until the temperature of the relay has stabilized.

35.6 When the temperature is stabilized, the coil shall not exceed the maximum temperature rises specified in Table 12. The phase-voltage sensing relay shall be undamaged and fully functional at the conclusion of the test.

36 Range of Operating Voltages

36.1 The transfer switch control circuit shall operate as intended with control voltages of any value from 85 percent of rated voltage up to 110 percent of rated voltage.

37 Overload Test

37.1 Transfer switches shall be subjected to an overload test, switching a test current of six times rated continuous current. The power factor of the circuit shall be 0.5 or less. The rate of operation shall be one operation every five minutes, or at a faster rate if desired. The number of operations shall be 50 for switches rated up to 1200 A, and 25 for switches rated higher than 1200 A.

37.2 Each operation shall comprise the following sequence of actions:

a) Transfer switch in the normal position.

b) Apply current from test station.

c) Carry current for 10 cycles minimum.

d) Transfer to alternate source.

e) Carry current for 10 cycles minimum.

f) Transfer to normal source.

g) Carry current for 10 cycles minimum.

h) Remove current via test station controls for maximum of 5 minutes.

There shall be no additional delay added to the transfer time that is inherent to the design. If the transfer time is adjustable this adjustment shall be set to minimum. Each operation shall be conducted on the basis of an open transition between sources.

37.3 The test circuit shall have an open circuit voltage of no less than 125 percent and a closed-circuit voltage no less than 120 percent of the maximum rated voltage of the transfer switch. During the test, the alternate source shall be displaced 120 electrical degrees from the normal source for a 3-phase supply.

37.4 Tests shall be conducted at rated frequency. The test (or tests) are to cover the conditions of maximum voltage, and current interrupted.

37.5 All sensing and control relays required for operation of the transfer switch shall be energized at their rated voltage and the relay contacts shall make and break their intended load.

37.6 Time delay, undervoltage, and frequency sensitive relays and the like may be bypassed to facilitate testing of the main power circuit contacts.

37.7 Reactive components of the load employed may be paralleled when of the air-core type, but no reactances shall be connected in parallel with resistances, except that an air-core reactor in any phase may be shunted by resistance (R_{SH}), the loss in which is approximately one percent of the total power consumption in that phase calculated in accordance with the following formula:

$$R_{SH} = 100\left(\frac{1}{PF} - PF\right)\frac{E}{I}$$

in which:

PF is the power factor;

E is the closed-circuit phase voltage; and

I is the phase current.

37.8 A transfer switch having a ventilated enclosure shall have a cotton pad indicator at least 12.7 mm (1/2 inch) thick attached to the outside of and completely covering any louvers or other openings. This cotton pad shall not ignite during the test.

37.9 The transfer switch shall be mounted in its intended enclosure. The frame and all other normally grounded parts (enclosure, drive mechanisms, etc.) shall be isolated from ground, but connected to ground through a 30 A maximum non-time delay fuse, having a voltage rating not less than the rating of the transfer switch. This connection shall be made with a minimum 5.26 mm^2 (10 AWG) copper wire, having a length of 1.2 – 1.8 m (4 – 6 feet). The ground fuse shall not open during the test.

37.10 At the conclusion of the test, the device shall be in operable condition, and shall meet the requirements of the Dielectric Voltage-Withstand Test (Repeated), 43. The fuse indicated in 37.9 shall not be open.

38 Electrical Endurance Test

38.1 When required by Table 7, the electrical endurance test shall be performed on transfer switches to verify that the interrupting devices meet the operating duty class in 5.11.

38.2 When the overload test of 37is required as noted in Table 7 for a particular construction, the electrical endurance test shall be conducted on the same sample subjected to the Overload Test, 37.

38.3 Transfer switches shall be subjected to an electrical endurance test consisting of the number of operations specified in 5.11 for the operating duty class at the rated continuous current. The power factor for the endurance test shall be between 0.7 and 0.8 lagging. Lower power factors may be used with the agreement of all concerned.

38.4 The rate of operation is not specified except that the last 10 operations shall be performed at intervals between operations no greater than 4 minutes.

38.5 Other test conditions shall be in accordance with 37.2 – 37.9.

38.6 At the conclusion of the test, the device shall be in operable condition, and shall meet the requirements of the Dielectric Voltage-Withstand Test (Repeated), 43. The fuse indicated in 37.9 shall not be open.

39 Temperature Test

39.1 Transfer switches when tested under the conditions described in 39.2 – 39.12 shall not attain a temperature at any point high enough to constitute a risk of fire or to damage any materials employed in the device, and shall not have temperature rises at specific points greater than those indicated in Table 12.

39.2 Two temperature tests are required: one with the transfer switch delivering power from the normal source, and the second with the transfer switch delivering power from the alternate source. For the temperature tests, the transfer switch shall be operated under intended use conditions and shall carry its test current continuously. A low-potential source of supply may be used for temperature tests on parts other than coils, which shall be tested at rated voltage. The tests on all parts shall be made simultaneously, as the heating of one part could affect the heating of another part.

39.3 The test current shall be 100 percent of the rated current. The frequency of the test current shall be the maximum rated frequency of the device (±2 Hz).

39.4 Terminals of transfer switches intended for cable connection shall be connected with not less than 1.2 m (4 feet) of copper wire per terminal. The wire size shall correspond to the rating of the transfer switch as specified in 13.4.1. When terminals are also intended for connection using bus bars, they shall be additionally tested in accordance with 39.5.

39.5 Terminals of transfer switches intended for connection using bus bars shall be tested with copper bus bars of the size shown in Table 13. The spacing between multiple bus bars shall be 6.4 mm (1/4 inch) or less with no intentional wider spacing except as required at the individual terminals of the transfer switch. As an alternate, the bus bar connections may utilize bus bars of the identical material, size, and arrangement as provided internally within the assembly. For either method, the conductors shall be at least 1.2 m (4 ft) in length. When the terminals are also intended for connection using cables, they shall be additionally tested in accordance with 39.4.

39.6 For a device employing a fuseholder, a copper bar, copper tubing, or an equivalent material with negligible impedance instead of a fuse shall be used during the test.

39.7 The thermocouple method consists of the determination of temperature by the application of thermocouples to the hottest accessible parts.

39.8 The resistance method consists of the determination of the temperature of a copper or aluminum winding by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature, according to the formula:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise;

R is the resistance of the coil at the end of the test;

r is the resistance of the coil at the beginning of the test;

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades must be determined.

t_1 is the room temperature °C at the beginning of the test;

t_2 is the room temperature °C at the end of the test.

39.9 As it is generally necessary to de-energize the winding before measuring R, the value of R at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time may be plotted and extrapolated to give the value of R at shutdown.

39.10 The temperature readings shall be obtained by means of thermocouples and an indicating instrument. A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 10 minute or more than 20 minute intervals, indicate that stable conditions have been reached.

39.11 The primary (preferred) method of measuring the temperature of a coil is the resistance method, but temperature measurements by either the thermocouple or resistance method are permitted, except that the thermocouple method shall not be employed for a temperature measurement at any point at which supplementary insulation is employed.

39.12 Temperatures shall be measured by thermocouples consisting of wires no larger than 0.21 mm^2 (24 AWG) and no smaller than 0.05 mm^2 (30 AWG). When thermocouples are used in determining temperatures in electrical equipment, thermocouples consisting of 0.05 mm^2 (30 AWG) iron and constantan wire and a potentiometer-type instrument shall be used whenever referee temperature measurements by thermocouples are necessary. The thermocouple wire shall conform with the requirements listed in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E 230/E 230M (refer to Annex B, Item 9). The thermocouples and related instruments shall be accurate and calibrated in accordance with good laboratory practice.

40 Mechanical Endurance Tests

40.1 Other than as noted in 40.2, a transfer switch shall operate in the intended manner without load for a minimum number of operations as set out in Table 14. The test may be conducted at any convenient rate of operation.

40.2 The mechanical endurance tests of 40.1 are not required when the switching components, together with all associated interlocks, have been subjected to mechanical endurance testing equal to or greater than the number of operations in Table 14 as part of the applicable component product standard(s).

40.3 At the end of this test the sample shall:

a) Have no breakage of parts;

b) Have no permanent deformation that impairs mechanical performance;

c) Have no permanent deformation resulting in more than a 10 percent reduction of electrical clearance; and

d) Comply with the Dielectric Voltage-Withstand Test (Repeated), 43.

40.4 The ability of any interlock to function in the intended manner shall not have been impaired.

40.5 The mechanical endurance test may be combined with the electrical endurance tests by subjecting one sample to both electrical and no-load operations. If the tests are combined, the required number of electrical endurance operations shall be conducted, followed by a number of no-load mechanical operations, such that the total of electrical operations, plus the no-load mechanical operations, is equal to or greater than the number of operations required by Table 14.

41 Dielectric Voltage-Withstand Test

41.1 A transfer switch device shall be capable of withstanding for 1 minute without breakdown the application of a 60 Hz sinusoidal potential as indicated in Table 16.

41.2 Tests shall be made under the temperature and humidity conditions normally prevailing at the test site with appropriate correction factors for relative air density and humidity applied as outlined in Annex B, Item 8. The equipment shall be clean and in good condition.

41.3 A transformer, coil, or similar device, or surge protection devices may be disconnected during these tests. Such devices shall be separately investigated.

41.4 The test voltage from Table 16, Column 2, shall be applied as follows:

a) With the transfer switch closed in the normal supply position, apply the test voltage between each individual phase of the normal supply source and the enclosure, with the enclosure, all other phases and isolated control circuits grounded;

b) With the transfer switch closed in the alternate supply position, apply the test voltage between each individual phase of the alternate supply source and the enclosure, with the enclosure, all other phases and isolated control circuits grounded;

c) With all isolating means closed and the transfer switch in the normal supply position, apply the test voltage between each individual alternate supply source terminal, and all other terminals, with all other terminals grounded; and

d) With all isolating means closed and the transfer switch in the alternate supply position, apply the test voltage between each individual normal supply source terminal, and all other terminals, with all other terminals grounded.

41.5 Test Across Isolating Distance

41.5.1 When the isolating distance is achieved by other than a drawout element, the test voltage from Table 16, shall be applied as follows:

a) With the transfer switch in the normal supply position and the isolating means in the open position, apply the test voltage between all the terminals of the normal supply source, and all the load terminals; and

b) With the transfer switch in the alternate supply position and the isolating means in the open position, apply the test voltage between all the terminals of the alternate supply source, and all the load terminals.

41.5.2 When isolating distance is achieved by a drawout element, the test voltage from Table 16, Column 3, shall be applied as follows:

a) With the normal source drawout element in the test position, and with its contacts closed, apply test voltage simultaneously between all terminals of the normal supply source, and all load terminals; and

b) With the alternate source drawout element in the test position, and with its contacts closed, apply test voltage simultaneously between all terminals of the alternate supply source, and all load terminals.

41.6 To determine whether a transfer switch complies with the requirements in41.1, the device shall be tested by means of a 500 VA or larger capacity transformer, the output voltage of which can be varied. The waveform of the voltage shall approximate a sine wave. The applied potential shall be increased gradually from zero to the required test value, and shall be held at that value for one minute. The increase in the applied potential shall be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter in the output circuit of the test transformer.

42 Partial Discharge Testing Procedures

42.1 When partial discharge tests are required, the maximum allowable partial discharge pulse magnitude shall be 100 pC per vertical section of a transfer switch assembly tested with the partial discharge extinction voltage specified in Table 15. Closed transition switches shall be tested with all switching devices in the closed position. Open transition switches shall be subjected to two tests: one with the normal source closed and the second with the alternate source closed.

42.2 Test procedure

42.2.1 Tests shall be conducted in accordance with the Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques – Partial Discharge Measurements, IEEE C37.301 (refer to Annex B, Item 26), except that the test procedure described in Annex B of the referenced document shall be replaced by the test procedure detailed in 42.2.2 – 42.2.4.

42.2.2 Partial discharge tests shall be conducted on each phase individually. The test voltage shall be applied between the phase under test and ground, with all other phases and the enclosure grounded. Voltage transformers, control power transformers, and surge protection devices may be disconnected for this test.

42.2.3 The voltage shall be applied to the test object and shall be gradually increased to twice the partial discharge extinction voltage shown in Table 15. The voltage shall be maintained at this pre-stress voltage for 60 s.

42.2.4 The voltage shall be gradually reduced to the partial discharge extinction voltage shown in Table 15. The partial discharge extinction voltage shall be maintained for 60 s and the discharge level shall be measured at the end of this period. The measured partial discharge level for each phase shall not exceed 100 pC per vertical section.

43 Dielectric Voltage-Withstand Test (Repeated)

43.1 The dielectric voltage-withstand test described in 41 shall be repeated following the Overload Test (37), Electrical Endurance Test (38), and Mechanical Endurance Test (40) utilizing the test voltage specified in Table 16, Column 4.

44 Withstand Test

44.1 When tested under the conditions described in 44.2 – 44.13, a transfer switch shall withstand the designated levels of current until the overcurrent protective devices designated in 44.3 open. At the conclusion of the test:

a) The switch shall be capable of being operated by its intended means;

b) There shall be no breakage of the insulators or other parts to the extent that the integrity of the mounting of live parts is impaired;

c) The door shall be prevented by its latch, without bolt or lock installed therein, from being blown open: deformation of the door alone is acceptable;

d) No conductor shall have pulled out of a terminal connector, and there shall be no damage to the conductor insulation or the conductor; and

e) For a plug in or drawout unit, the point of contact shall be the same both mechanically and electrically as before the test.

44.2 The tests specified in 44.1 shall be performed on both the normal source and alternate source circuits, unless the construction of the normal and alternate source circuits are representative of each other, in which case the test need be conducted on only one circuit.

44.3 The overcurrent protective devices specified in 44.1 shall be one of the following:

a) The integral circuit breaker provided in the transfer switch, with protective relaying set at the least responsive setting when such circuit breaker is part of the design; or

b) The maximum ampere rated fuse that can be inserted when integral fuseholders are provided.

44.4 The test current shall be maintained until the overcurrent protection device noted in 44.3 opens the circuit.

44.5 A transfer switch shall be tested with alternating current at rated frequency on a circuit as indicated in Figure 3. The test shall be performed in accordance with the following:

a) The open-circuit voltage of the power-supply circuit shall be not less than the maximum rated voltage of the switch.

b) The test circuit (see Figure 3), with the transfer switch assembly short-circuited at its line terminals, shall be capable of producing a three-phase fault with a prospective current (symmetrical) at least equal to the short-circuit current rating of the transfer switch assembly (see 54.10). The rms current value is based on the average symmetrical current in the three phases (i.e., omitting any dc component). Also, the test circuit shall be capable of producing a peak current at the major peak of the maximum cycle in an outer phase of at least 2.6 times the short-circuit current rating.

c) If fused, the transfer switch assembly shall have the highest ampere rated fuses that the transfer switch assembly can accommodate. If the transfer switch assembly is intended to be used with more than one type or make of medium-voltage fuse, the test shall be conducted using the fuse having the highest let-through characteristics. The characteristics referred to are peak let-through current (I_p) and ampere-squared-seconds (I^2t).

d) The test source circuit shall include the necessary measuring equipment.

44.6 The reactive components of the impedance in the line shown in Figure 3 may be paralleled when of the air-core type, but no reactance shall be connected in parallel with resistances, except that an air-core reactor(s) in any phase may be shunted by resistance as determined in accordance with 37.7.

44.7 For the performance of the test, the load terminals of the switch shall be short-circuited by a bus bar having an ampacity no less than the continuous current rating of the transfer switch. Cables may be used in lieu of bus bars, and shall be sized in accordance with Table 3.