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NEMA STANDARDS PUBLICATION

ICS 10

INDUSTRIAL CONTROL AND SYSTEMS AC TRANSFER EQUIPMENT

PART 2: STATIC AC TRANSFER EQUIPMENT

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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NEMA Standards Publication No. ICS 10-1999

Industrial Control and Systems
AC Transfer Equipment

Part 2: Static AC Transfer Equipment

Published by

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FOREWORD

This Standards Publication was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA.

ICS 10-1999, Part 2 is a continuation of ICS 10-1993 which superseded Part ICS 2-447 of NEMA Publication ICS 2-1988.

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or not control over the following factors which are vital to a safe installation:

1. Environmental conditions
2. System design
3. Equipment selection and application
4. Installation
5. Operation practices
6. Maintenance

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions.

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Rosslyn, Virginia 22209

This Standards Publication was developed by the Industrial Control and Systems Section. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Section was composed of the following members:

ABB Control, Inc.—Wichita Falls, TX
ABB Industrial Systems—New Berlin, WI
Alstrom Drives and Controls, Inc.—Pittsburgh, PA
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Control Concepts—Beaver, PA
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Lincoln Motors—Cleveland, OH
MagneTek—New Berlin, WI
Master Control Systems, Inc.—Lake Bluff, IL
Metron, Inc.—Denver, CO
Micro Mo Electronics—Clearwater, FL
Mitsubishi Electric Automation, Inc.—Vernon Hills, IL
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STATIC AC TRANSFER EQUIPMENT

1 SCOPE

The standards in this part apply to static automatic and static nonautomatic transfer equipment without cross-connection of sources during transfer or retransfer, with or without bypass isolation switches rated 600 volts AC or less, not exceeding 6000 amps, for use on single-phase and polyphase AC circuits.

Static transfer equipment that does have cross-connection of sources during transfer or retransfer is outside the scope of this standard.

1.1 General

The definitions and standards of ICS 1, except for clause 7 pertaining to spacings as indicated, also apply to this standard.

These requirements cover solid state automatic transfer equipment intended for use in ordinary locations to provide for lighting and power only in optional stand-by systems in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70.

1.2 Normative References

In this NEMA Standards Publication, reference is made to the following standards listed below. Copies are available from the indicated sources.

National Electrical Manufacturers Association
1300 North 17th Street
Rosslyn, Virginia 22209

ICS 1-1993	*Industrial Control and Systems General Requirements*
ICS 1.3-1986 (R1991)	*Preventive Maintenance of Industrial Control and Systems Equipment*
MG 1-1998	*Motors and Generators*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 869A	*Service Equipment*
UL 1008	*Transfer Switch Equipment*

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

NFPA 70	*National Electrical Code (NEC)*
NFPA 99	*Health Care Facilities*

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2 DEFINITIONS

For the purposes of this NEMA Standards Publication, the following definitions apply.

2.1 Transfer Equipment

bypass isolation switch: A manually operated device used in conjunction with transfer equipment to provide a means of directly connecting load conductors to a power source and of disconnecting the transfer equipment.

A bypass isolation switch may be supplied with an automatic or nonautomatic transfer equipment.

static automatic transfer equipment: Self-acting equipment using electronic power devices for transferring one or more load conductor connections from one power source to another.

Static automatic transfer equipment may include logic to inhibit automatic operation in either or both directions, provided the equipment reverts to automatic operation upon loss of power to the load.

Static automatic transfer equipment may be supplied with or without a bypass isolation switch.

static nonautomatic transfer equipment: Manually controlled equipment using electronic power devices for transferring one or more load conductor connections from one power source to another.

Nonautomatic transfer equipment may be supplied with or without a bypass isolation switch.

2.2 Operation of Static Transfer Equipment

conditional short-circuit rating: The available rms symmetrical current that transfer equipment can satisfactorily withstand for a total operating time of the overcurrent protective device under specified conditions of use and behavior. (See clause 4.1.6)

cross connection of sources: The flow of current, excluding normal leakage currents, between sources during transfer.

NOTE—Static transfer equipment that does have cross-connection of sources during transfer or retransfer is outside the scope of this standard.

monitored source deviation: A variation in the power source being monitored that signals the transfer equipment to operate.

For clarification of terms:

a. Typical variations that may be detected are changes in voltage and frequency.
b. "Transfer Signal" is a term used to describe the signal that is initiated by the monitored source deviation and that signals the transfer equipment to operate.

total system transfer time: The time interval, including any purposely introduced time delays and engine-generator start-up times, during which the power to the load deviates from the allowable tolerances. "Total System Transfer Time" is a parameter of the total system and not solely of the transfer equipment.

transfer time: The time interval during transfer in which the power to the load deviates from the allowable tolerances.

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3 CLASSIFICATIONS

Transfer equipment is classified as Type A or Type B as follows:

Type A: Transfer equipment that is not intended to provide required overcurrent (overload and short-circuit) protection.

Type B: Transfer equipment that is intended to automatically provide required overcurrent (overload and short-circuit) protection.

4 CHARACTERISTICS AND RATINGS

4.1 Rated and Limiting Values for the Main (Power) Circuit

4.1.1 System Voltage Ratings

The system voltage rating of transfer equipment shall be 120, 208, 220, 240, 400, 415, 480, or 600 volts AC, single phase or polyphase.

4.1.2 Continuous Current Rating

The continuous current rating of transfer equipment shall be based on an ambient temperature of 40°C.

4.1.3 Rating Based on Load Characteristics

Transfer equipment shall be rated for one or more of the following types of loads:

a. Total system load consisting of any combination of motors, electric discharge lamps, electric heating (resistive) loads, and tungsten lamp loads, provided the latter does not exceed 30 percent of the continuous current rating of the transfer equipment.
b. Tungsten lamp load consisting entirely of tungsten lamps.
c. Electric discharge lamp load consisting entirely of electric discharge lamps, including fluorescent lamps.
d. Resistive load consisting of heater and other noninductive loads in which the inrush current does not exceed 150 percent of the continuous current rating of the equipment.

4.1.4 Interrupting Rating

Current interrupting ratings shall be expressed in rms symmetrical amperes.

4.1.5 Motor Starter Rating

Transfer equipment intended for a load consisting of a single motor may include overload relays and may be rated in horsepower or in full-load and locked-rotor current.

4.1.6 Withstand and Closing Ratings

Transfer equipment shall have withstand and closing ratings, expressed in maximum available fault current (rms symmetrical amperes) at maximum rated voltage, and marked in accordance with UL 1008 and this standard. The type and rating of any associated protective devices necessary to meet the requirements of UL 1008 shall also be marked on the transfer equipment.

The withstand and closing current rating shall be one of the values specified in Column 1 of Table 2-4-1.

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Standard withstand and closing ratings are based on transfer equipment testing conducted at maximum allowable test circuit power factors and corresponding minimum X/R ratios specified in Table 2-4-1. When applying transfer equipment, consideration should be given to both available fault *current and circuit X/R ratio at the point of application.*

4.1.7 Overcurrent Protection

Each service, feeder, and branch circuit should have the appropriate short-circuit, ground-fault, and overload protection, provided either externally or as an integral part of the transfer equipment.

Table 2-4-1
AVAILABLE FAULT CURRENTS AND RESPECTIVE TEST POWER FACTORS AND CORRESPONDING X/R RATIOS

Withstand and Closing Rating (rms symmetrical amperes)	Maximum Test Power Factor*	Minimum Corresponding X/R Ratio*
5,000	0.50	1.73
7,500	0.50	1.73
10,000	0.50	1.73
14,000	0.30	3.18
18,000	0.30	3.18
22,000	0.20	4.90
25,000	0.20	4.90
30,000	0.20	4.90
35,000	0.20	4.90
42,000	0.20	4.90
50,000	0.20	4.90
65,000	0.20	4.90
85,000	0.20	4.90
100,000	0.20	4.90
125,000	0.20	4.90
150,000	0.20	4.90
200,000	0.20	4.90

5 PRODUCT MARKING, INSTALLATION, AND MAINTENANCE INFORMATION

5.1 Markings

5.1.1 Transfer Equipment

The nameplate markings for transfer equipment shall include:

a. Name of manufacturer and catalog number, or the equivalent serial number.
b. Voltage and frequency ratings.
c. Continuous current rating.

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Additional markings shall be those required by UL 1008 and shall include the following, where applicable:

a. Suitability for specific loads. See 4.3.5 of UL 1008.
b. Suitability for use as service equipment.
c. Interrupting or short-circuit ratings.
   1. For Type A: Short-circuit rating or conditional short-circuit rating with the type and rating of the additionally required short-circuit protective device.
   2. For Type B: Interrupting rating.
d. Cautions or warnings, or both.
e. Automatic or nonautomatic.

5.1.2 Bypass Isolation Switch Equipment

The nameplate markings for bypass/isolation switches shall include:

a. Name of manufacturer and catalog number, or the equivalent serial number.
b. Voltage and frequency ratings.
c. Continuous current rating.

5.1.3 Control Circuits

Transfer equipment control circuits shall meet the marking requirements of UL 1008.

5.2 Maintenance of Transfer Equipment

A maintenance program and schedule should be established for each particular installation to assure minimum down time. The program should include periodic testing, tightening of connections, inspection for evidence of overheating and excessive contact erosion, removal of dust and dirt, and replacement of contacts when required.

See NEMA Standards Publication ICS 1.3 for preventive maintenance instructions.

6 SERVICE AND STORAGE CONDITIONS

ICS 1, Clause 6 applies.

7 CONSTRUCTION

7.1 Spacings

Except as otherwise specified in the following paragraphs, spacings in automatic transfer equipment and bypass isolation switches shall be not less than those shown in Table 2-7-1.

7.1.1 The spacings on printed wiring assemblies may be as small as 0.031 inch where the power to the printed wiring assembly is limited and transient voltages are controlled as specified in ICS 1, Clause 7.

7.1.2 The spacings given in Table 2-7-1 do not apply to snap switches, lampholders, and similar wiring devices that are used as a part of transfer equipment.

7.1.3 In a circuit involving potentials of not more than 50 VAC, the spacings at field-wiring terminals may be 0.125 inch (3.2 mm) through air and 0.250 inch (6.4 mm) over the surface, and the other spacings may

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be 0.053 inch (1.4 mm) through air and over the surface, provided that insulation and clearances between the low-potential circuit and any high-potential circuit are in accordance with the requirements that are applicable to the high-potential circuit.

7.2 Test Switch

An external test switch or terminals for connection to an external test switch shall be provided. Such a test switch shall be connected so that operation of the test switch simulates a failure of the normal power source.

7.3 Interlocks and Protective Circuits

Transfer equipment shall meet the requirements of UL 1008 for interlocks and protective circuits.

7.3.1 Protection from Cross-Connection

The electronic circuitry of transfer equipment shall have provisions to reduce the possibility of inadvertent cross-connections.

7.3.2 Bypass Isolation Switch Interlock

Bypass isolation switches shall be provided with necessary interlocks to prevent the unintentional simultaneous connection of two power sources. In addition, bypass isolation switches provided with overlapping contacts shall be provided with a means of interlocking to prevent the opening of nonload-break contacts under load.

7.4 Service Equipment

Transfer equipment which is designed to be suitable for use as service equipment shall comply with the requirements in UL 1008, UL 869A *Service Equipment*, and:

a. Have spacings in accordance with Table 2-7-1, Item 2.
b. Have accessible independent disconnecting means for both the normal and alternate power sources
c. Be marked "suitable for use as service equipment."
d. Where provided with a neutral, have provision for connection of the service grounding conductor to the neutral terminal in accordance with Table 2-7-2.
e. Be provided with ground-fault protection where applied on solidly grounded wye electrical services of more than 150 VAC to ground, but not exceeding 600 VAC phase-to-phase for each service disconnect rated 1000 amperes or more.
f. The control circuit shall have short-circuit protection and a disconnecting means suitable for the available current of the supply, where the control circuit is located ahead of the service disconnecting means.
g. Be provided with overcurrent protection either immediately adjacent to, or as part of, the transfer equipment disconnecting means.

7.5 Emergency Power Circuit Service

The alternate source for emergency systems shall not be required to have ground-fault protection of equipment.

7.6 Control Circuits

Transfer equipment shall be exempted from the motor control circuit overcurrent protection requirements of ICS 1, Clause 7.

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Table 2-7-1
SPACINGS

		Minimum Spacings (inches) Nominal Operating Voltage		
		51-150 Volts	151-300 Volts	301-600 Volts
1. Power Circuits Rated Not More Than 400 Amperes and Control Circuits				
a. Between any uninsulated live part and (1) an uninsulated live part of the opposite polarity and (2) an exposed metal part.*	through air or oil	0.125 (3.2 mm)	0.250 (6.4 mm)	0.375 (9.5 mm)
	over surface	0.250 (6.4 mm)	0.375 (9.5 mm)	0.500 (12.7 mm)
b. Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable.**	shortest distance	0.500 (12.7mm)	0.500 (12.7mm)	0.500 (12.7 mm)
2. Power Circuits Rated Over 400 Amperes and Service Equipment				
a. Between any uninsulated live part and an uninsulated live part of the opposite polarity.	through air or oil	0.500 (12.7mm)	0.750 (19.1mm)	1.000* (25.4 mm)
	over surface	0.750 (19.1mm)	1.250 (31.8mm)	2.000 (50.8 mm)
b. Between any uninsulated live part and an uninsulated grounded part, exposed metal part, or the walls of a metal enclosure, including fittings for conduit or armored cable.**	through air or oil	0.500 (12.7mm)	0.500 (12.7mm)	1.000† (25.4 mm)

*The spacing between wiring terminals of opposite polarity and the spacing between a wiring terminal and a ground part shall be not less than 0.250 inch (6.4 mm) if short-circuiting of grounding of such terminals may result from projecting strands of wire.

** For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce spacings between the metal piece and uninsulated live parts.

† The through-air spacing may be not less than 0.500 inch (12.7 mm) at the main terminals and also between grounded dead metal and the neutral of 277/480-VAC, 3-phase, 4-wire transfer equipment.

Table 2-7-2
SIZE OF GROUNDING CONDUCTORS

Size of Largest Service Conductor or Equivalent Size of Multiple-conductor Cables		Size of Grounding Conductor	
Copper	Aluminum	Copper	Aluminum
2 AWG or smaller	0 AWG or smaller	8 AWG	6 AWG
1 or 2 AWG	2/0 or 3/0 AWG	6 AWG	4 AWG
2/0 or 3/0 AWG	4/0 AWG or 250 kcmil	4 AWG	2 AWG
Over 3/0 AWG to 350 kcmil	Over 250 to 500 kcmil	2 AWG	0 AWG
Over 350 to 600 kcmil	Over 500 to 900 kcmil	0 AWG	3/0 AWG
Over 600 to 1100 kcmil	Over 900 to 1750 kcmil	2/0 AWG	4/0 AWG
Over 1100 kcmil	Over 1750 kcmil	3/0 AWG	250 kcmil

*The equivalent size for multiple conductor cables shall be the sum of the circular-mil areas of the individual conductors.

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8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 Performance Requirements

8.1.1 Control Circuits

Transfer equipment control circuits shall meet the overcurrent and mechanical protection requirements of UL 1008.

8.1.2 Ground-Fault Protection

Where ground-fault protection is provided, the performance requirements are as follows:

a. The maximum setting of the ground-fault protection shall be 1200 amperes.
b. The maximum time delay shall be one second for ground-fault currents equal to or greater than 3000 amperes.
c. In health care facilities, the ground-fault protection on the service disconnect must be coordinated with the ground-fault protection on the next downstream feeder to ensure 100 percent selectivity such that the feeder device and not the service disconnect shall open on ground faults on the load side of the feeder device. There shall be a minimum time separation of six cycles between tripping bands.

8.1.3 Undervoltage Monitoring Characteristics

Unless otherwise specified, transfer equipment shall have provision for initiating the transfer of load conductor connections to an alternate power source when the voltage on any phase of the normal power source falls below 70 percent of rated voltage. Provision shall also be made for transferring the connections back to the normal power source when the voltage on all phases of the normal power source returns to at least 90 percent of rated voltage.

Voltage critical loads may require adjustable voltage-monitoring and control means.

8.2 Design Tests

8.2.1 Required Testing

Transfer equipment and bypass isolation switches shall be capable of meeting required performance tests as specified in UL 1008 for static transfer equipment.

Static transfer equipment shall not permit current flow between sources under any normal operating condition. Design of control circuits shall guard against current flow between sources with single source failures. To test for cross currents in each phase, the instantaneous currents I_1, I_2, and I_L (see figure 2-8-1) shall be displayed or recorded and shown to be related as:

$$|I_1| + |I_2| = |I_L|$$

Inequality outside of measurement error indicates a cross current and failure of the test.

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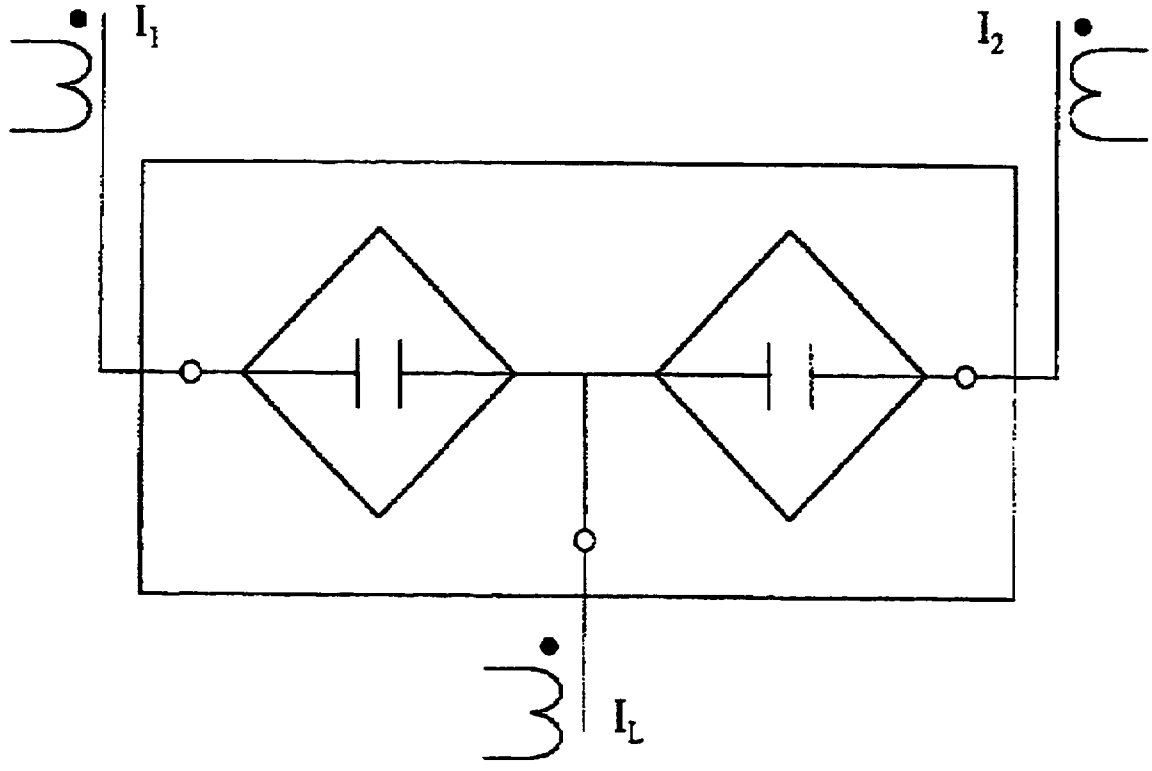


Figure 2-8-1
CROSS CURRENT TEST CIRCUIT DIAGRAM

8.2.2 Optional Performance Verification

The following verifications are performance capabilities that may be declared by the manufacturer.

8.2.2.1 Total System Transfer Time and Transfer Time – In Phase Transfer

a. Open circuit one source
b. Short-circuit one phase, one source
c. Short-circuit three phase, one source
d. Output short-circuit

8.2.2.2 Total System Transfer Time and Transfer Time – Out of Phase Transfer

a. Open circuit one source
b. Short-circuit one phase, one source
c. Short-circuit three phase, one source
d. Output short-circuit

8.2.2.3 Non-Linear Loads

See Annex A for a discussion on non-linear loads.

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9 APPLICATION

9.1 AC Transfer Equipment Specification

The following characteristics should be specified in order to properly match the transfer equipment to the system:

a. Voltage.
b. Number of phases.
c. Number of wires.
d. Frequency.
e. Number of switched poles.
f. Type of load as defined in 4.1.3.
g. Continuous current or horsepower, or both, requirements of the load.
h. Available fault current.
i. Whether it is necessary to disconnect the load from both power sources simultaneously.
j. Whether the switch is to be suitable for use as service equipment.
k. Whether the switch is to include integral overcurrent protection.
l. Whether it is necessary to provide a bypass isolation switch in conjunction with the transfer. equipment. Where a bypass isolation switch is provided, it should be compatible with the transfer equipment.
m. Number of sources.

9.2 Power Quality

The transfer equipment shall be capable of transferring sensitive loads, such as computers and process controllers, between the preferred and alternate power sources without interrupting their normal operation. Examples of total system transfer time criteria applicable for most power quality applications are shown in Figure 2-9-1 taken from IEEE 446-1995. The Information Technology Industry Council (ITI) published another criteria applicable to 120-volt single-phase load equipment in 1996 (see figure 2-9-2).

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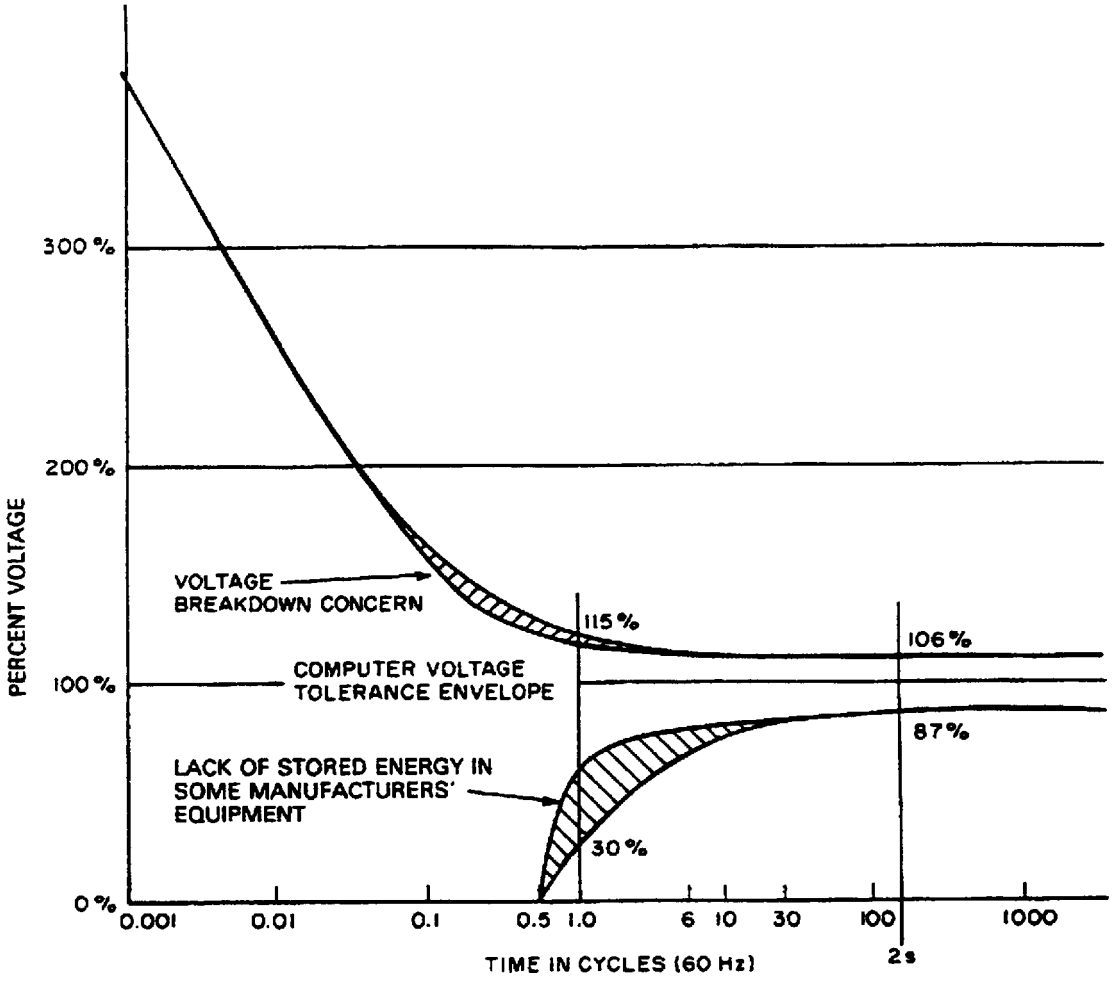
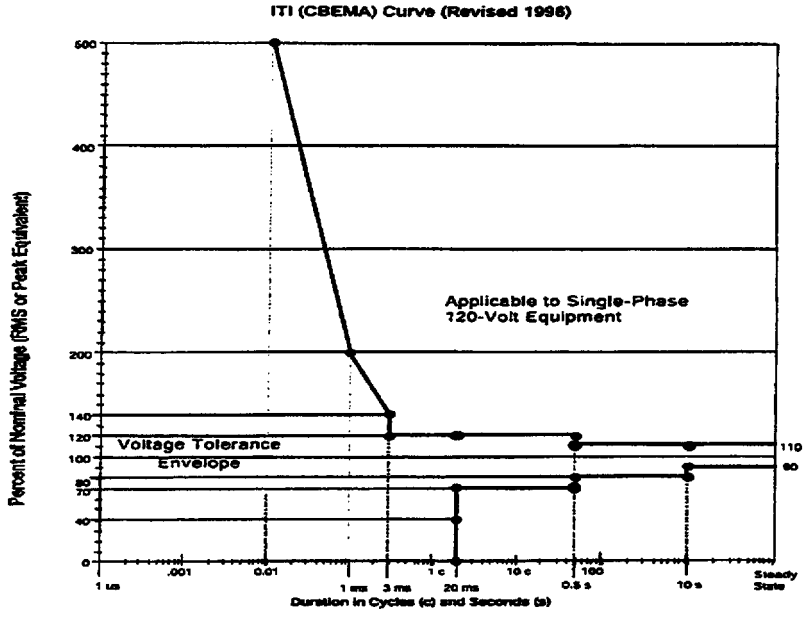


Figure 2-9-1
TYPICAL DESIGN GOALS OF POWER-CONSCIOUS COMPUTER MANUFACTURERS

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Figure 2-9-2
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9.3 Motor Transfer

Motors rated approximately 50 horsepower and greater are susceptible to damage when, in an ON-OFF-ON operation, they are switched before the residual motor voltage has decayed to a safe level. The high abnormal currents that may result from the out-of-phase relationship between the motor's residual voltage and the voltage of the reconnected power source may also trip overcurrent protective devices and, therefore, should be avoided. Consideration should be given to include controls in AC transfer equipment to minimize these abnormal currents.

For a more in depth treatment of motor transfer, see the section on bus transfer and reclosing in NEMA Standard MG 1.

9.4 Features for Particular Applications

Some conditions or requirements of particular applications may make additional features necessary. These may include the following:

a. Time delay to override monitored source deviation—A fixed or adjustable time delay which delays all signals for operation. This time delay prevents starting of the engine or the transfer of the load from the normal power source to the alternate power source during momentary voltage dips or disturbances of the normal power source.

b.* Time delay before transfer to alternate power source—A fixed or adjustable time delay which delays the transfer of the load to an available alternate power source. This delay allows an engine-generator time to stabilize at rated voltage and frequency before accepting the load.

c. Time delay before transfer to normal power source—An adjustable time delay which inhibits transfer of the load back to the normal power source. This delay allows the normal power source time to stabilize before accepting the load. The time delay may be automatically nullified if the alternate power source fails and power is available at the normal power source.

d.* Time delay before engine shutdown—A fixed or adjustable time delay which delays the shutdown of the engine-generator (alternate power source) after the load is transferred back to the normal power source. This delay allows the engine to run at no load and thereby minimizes the possibility of shutdown due to an increase in the temperature of the cooling water. It also permits the immediate transfer of the load back to the engine-generator in the event that the normal power source has not fully stabilized.

e.* Time delay to limit cranking—A fixed or adjustable time delay to limit the cranking time of the engine-generator if the engine fails to start when the normal power source fails.

f.* Engine exerciser—A programmable time switch to initiate the starting of the engine-generator for a preset period of time at preset intervals without transferring the load from the normal to the alternate power source.

Caution: No load operation may be detrimental to the engine, and the engine generator manufacturer should be consulted. Paragraph (g) would be considered.

g.* Alternate system exerciser—A programmable time switch to initiate the starting of the engine-generator and to transfer the load from the normal to the alternate power source for a preset period of time at preset intervals. The load is transferred back to the normal power source at the end of the exercise period.

Provision should be made for the initiation of immediate retransfer to the normal source in the event of an engine generator failure during the exercise period.

h. Auxiliary contact—A contact, other than the power circuit contacts, that is part of transfer equipment and is available for connection by the user. The number of auxiliary contacts, mode of operation, and function of each contact should be specified.

i*. Engine start contact—A contact that initiates cranking of the engine generator set when the normal power source fails.

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j. Alternate source monitor—A device(s) that monitors voltage or frequency, or both, of the alternate power source, and inhibits transfer to the alternate source until the monitored parameters reach specified levels.

k. Test switch—A switch to simulate failure of the normal power source, causing transfer of the load to the alternate power source.

l. Close-differential protection—A device(s) that monitors all lines of the normal power source and initiates transfer of the load from the normal power source to the alternate power source when any line of the normal power source drops below a predetermined value of voltage. It initiates transfer of the load back to the normal power source when all lines of the normal power source return to within specified limits. This feature is generally used for installations where only a limited reduction in voltage can be tolerated.

m. Time-delay-bypass switch—A momentary contact switch that initiates immediate transfer of the load back to the normal power source, bypassing any optional time delays.

n. Manual return-to-normal switch—A momentary contact switch that initiates transfer from the alternate to the normal power source where automatic transfer is not desired.

o. Overcurrent protection—The addition of elements to permit the transfer equipment to provide running overcurrent protection for a single motor.

p. Service equipment—See 7.4.

q. In-phase monitor—A device that monitors the relative voltage and phase angle between the power source to be transferred to and the power from which the transfer is to be made, and initiates transfer when acceptable values of voltage and phase angle are present. Such a device may function on the transfer from either power source.

r. Delayed transition—Provides a timed disconnection of the load from the power sources during transfer, primarily to allow decay of motor residual voltage.

s. Load disconnect device—A device that initiates opening of a pilot contact prior to transfer from either source and then provides a timed closure after transfer. It is used primarily to allow decay of motor voltage without affecting the speed of transfer.

t. Bypass isolation switch—A switch that may provide any of the following features or functions:

   1. Load-break contacts.
   2. Overlapping contacts.
   3. Combination of 1 and 2.
   4. Single-source bypass.
   5. Dual source bypass.
   6. Total isolation of the transfer equipment for purpose of maintenance, testing, modification, or repair. A bypass isolation switch can function as an independent nonautomatic transfer equipment.

u. Preferred Source Selectability—Allows the user to assign either power source to be the preferred, or normal, source.

v. Automatic Restart—Allows the transfer equipment to automatically restart when any power source becomes available after a simultaneous outage on all sources. This will prevent the load from being without power for an indeterminate period of time by overriding the standard operating mode which requires the user to manually restart the equipment.

w. Local/Remote Selector—Provides a means to allow the transfer equipment to be controlled from a remote location.

x. Reverse Power Flow Sensing—Detection of reverse power flow to the source

*Applicable to installations where the alternate power source is an engine-generator set.

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9.5 Considerations for Non-Linear Load Applications

Applications for non-linear loads may require special consideration. See Annex A for further information.

9.6 Graphical Symbol for Static Transfer Equipment

Figure 2-9-3 shows the preferred graphical symbol for static transfer equipment.

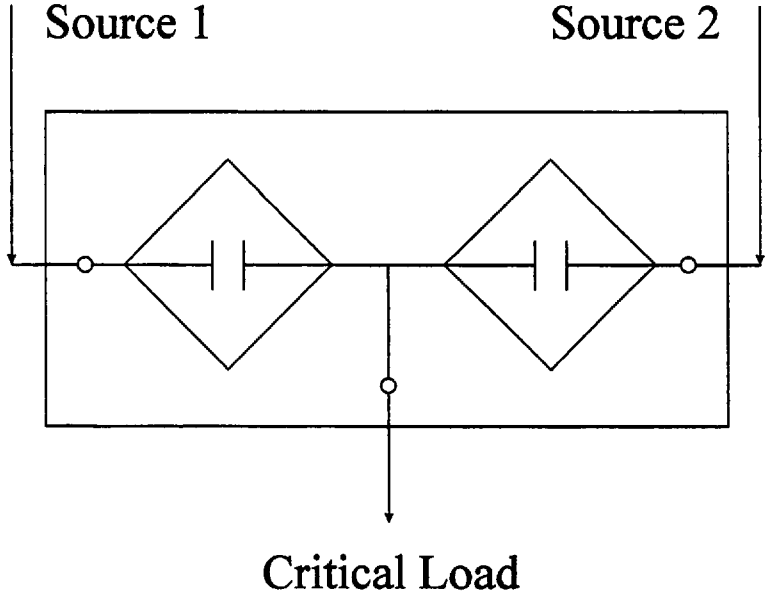


Figure 2-9-3
STATIC TRANSFER EQUIPMENT

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10 ANNEX A — NON-LINEAR LOADS

10.1 General

Static AC Transfer Equipment may be used to perform high speed power transfers to protect sensitive non-linear electrical loads from voltage sags, swells, and other power anomalies, including outages. One form of non-linear load is analytically described by its nominal 3:1 Crest Factor characteristic. The predominant example of a 3:1 Crest Factor load is the switch-mode power supply commonly found in computers and other electronic data processing equipment.

10.2 Non-Linear Electrical Load

Non-linear electrical loads do not behave according to the simple linear relationship proposed by Ohm's law. They are generally described by:

$$I = F(V)$$

Where F = a non-linear mathematical function, or

$$i = f(t)$$

Where f = a function of time.

The current-voltage relationship for popular electronic devices such as diodes or bi-polar junction transistors is well-known. However, when these solid-state devices are used to form complex systems like converters/inverters and switch-mode power supplies, the current-voltage relationship becomes difficult, at best, to express analytically. Fortunately, any rational function can be expressed as a linear sum of sines and cosines. In other words, the steady-state current wave form can, in general, be expressed as*:

$$i(t) = A\sin(\omega t) + B\sin(3\omega t) + C\sin(5\omega t) + D\sin(7\omega t) + \ldots$$

In simple terms, this means that non-linear electrical loads draw currents that are (odd multiple) harmonics of the intended (60 Hz) current.

The proliferation of electronic loads, such as computers and motor drives, has increased the proportion of harmonic currents (as compared to the fundamental 60 Hz) that exist in the facility electrical system.

10.3 Crest Factor (CF) of a System

A measure of the ratio of the peak to the root-mean-square (RMS) value of a wave form:

$$CF = \frac{Peak\ Value}{RMS\ Value}$$

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* For the advanced reader: This implies, without further explanation, that even-harmonic terms cancel in the Fourier series expansion of the function f(t). Moreover, a nonlinear load draws current described by:

$$i(t) = A\sin(\omega t)$$

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Where:

$$CF_{Pure\ sine\ wave\ (linear\ load)} = \sqrt{2} = 1.414$$

$$CF_{Current\ drawn\ by\ a\ computer} \cong 3$$

A Crest Factor $> \sqrt{2}$ of the current drawn by a load is one measure of the non-linearity of the load.

Figure A-2 shows the current drawn by a switch mode power supply.

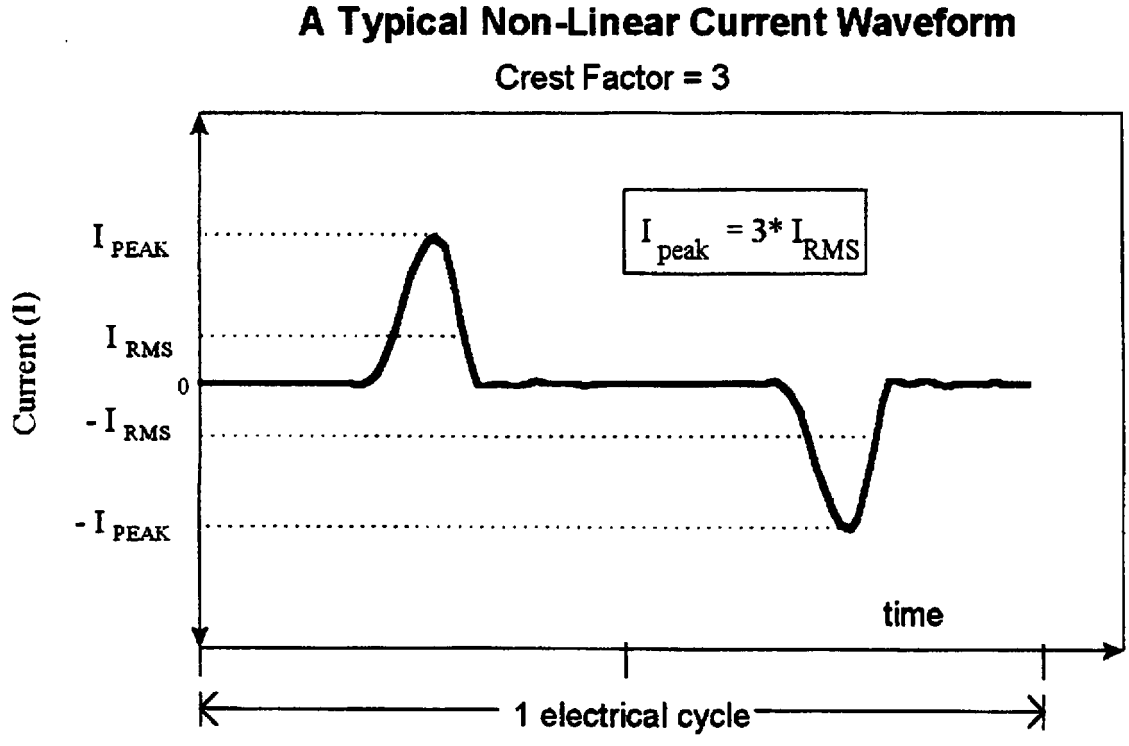


Figure A-2
TYPICAL NON-LINEAR CURRENT WAVEFORM

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