

IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

Sponsor
**Switchgear Committee
of the
IEEE Power Engineering Society**

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Abstract: Low-voltage metal-enclosed switchgear, which can contain either stationary or drawout, manually or electrically operated low-voltage ac or dc power circuit breakers in individual grounded metal compartments, in three-pole, two-pole, or single-pole construction is covered. Rated maximum voltage levels can be 254 V, 508 V, or 635 Vac and 300/325 V, 800 V, 1000 V, 1600 V, or 3200 Vdc. The continuous current ratings of the main bus in ac designs can be 1600 A, 2000 A, 2500 A, 4000 A, 6000 A, 8000 A, 10,000 A, or 12,000 A. The switchgear can also contain associated control, instruments, metering, protective, and regulating devices as necessary. The standard deals with service conditions, ratings, temperature limitations, and classification of insulating materials, insulation (dielectric) withstand voltage requirements, test procedures, and application.

Keywords: common related terms, control, cumulative loading, current transformers, drawout, indoor, instrumentation, load current-carrying, metering, outdoor, protection, qualifying terms, stationary

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Introduction

(This introduction is not a part of IEEE Std C37.20.1-1993, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.)

This standard has been revised to reflect needed technical changes that have been suggested since the original document was published in 1987.

This standard includes the requirements for only metal-enclosed low-voltage power circuit breaker switchgear. These requirements were previously a part of IEEE Std C37.20-1969 (Reaff 1981), IEEE Standard for Switchgear Assemblies Including Metal-Enclosed Bus (1974 consolidated edition). Other types of equipment previously included in IEEE Std C37.20-1969 (Reaff 1981), will be incorporated in separate publications.

IEEE Std C37.20-1969¹ has for many years covered all switchgear assemblies, including metal-enclosed bus. Standards committees of the IEEE Switchgear Assemblies Subcommittee and the NEMA Power Switchgear Assemblies Technical Committee recommended that the document be further developed and, where appropriate, that the various sections be identified with their own standards. This approach also identifies with the Conformance Test Procedure Standards.

The IEEE Switchgear Assemblies Committee, in cooperation with the NEMA Power Switchgear Assemblies Technical Committee, was responsible for this revision.

NEMA is responsible for developing clauses 4. and 6.. The Switchgear Assemblies Committee of the IEEE Switchgear Committee is responsible for developing clauses 2., 3., 5., 7., and 8..

A Working Group of the NEMA Power Switchgear Assemblies Technical Committee revised IEEE Std C37.23-1970, IEEE Guide for Calculating Losses in Isolated-Phase Bus to include clause 8. of IEEE Std C37.20. The document updates the material for metal-enclosed conductors including cable bus. The IEEE Switchgear Assemblies Committee refined and expanded the document.

This publication is one of a series covering Switchgear Assemblies as follows (see figure A):

IEEE Std C37.20.1-1993	Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear (1000 V and Below)
IEEE Std C27.20.2-1993	Metal-Clad and Station-Type Cubicle Switchgear (Above 1000 V)
IEEE Std C37.20.3-1987	Metal-Enclosed Interrupter Switchgear (Above 1000 V)
IEEE Std C37.21-1985	Control Switchboards
IEEE Std C37.23-1987	IEEE Standard for Metal-Enclosed Bus and Guide for Calculating Losses in Isolated Phase Bus

Through this joint effort over the many years, the switchgear assemblies standards have been of extreme value to the industry. Further suggestions for improvement gained in the use of this standard will be welcomed.

¹IEEE Std C37.20-1969 has been withdrawn. This standard was delineated into the various branches of the IEEE Std C37.20 series.

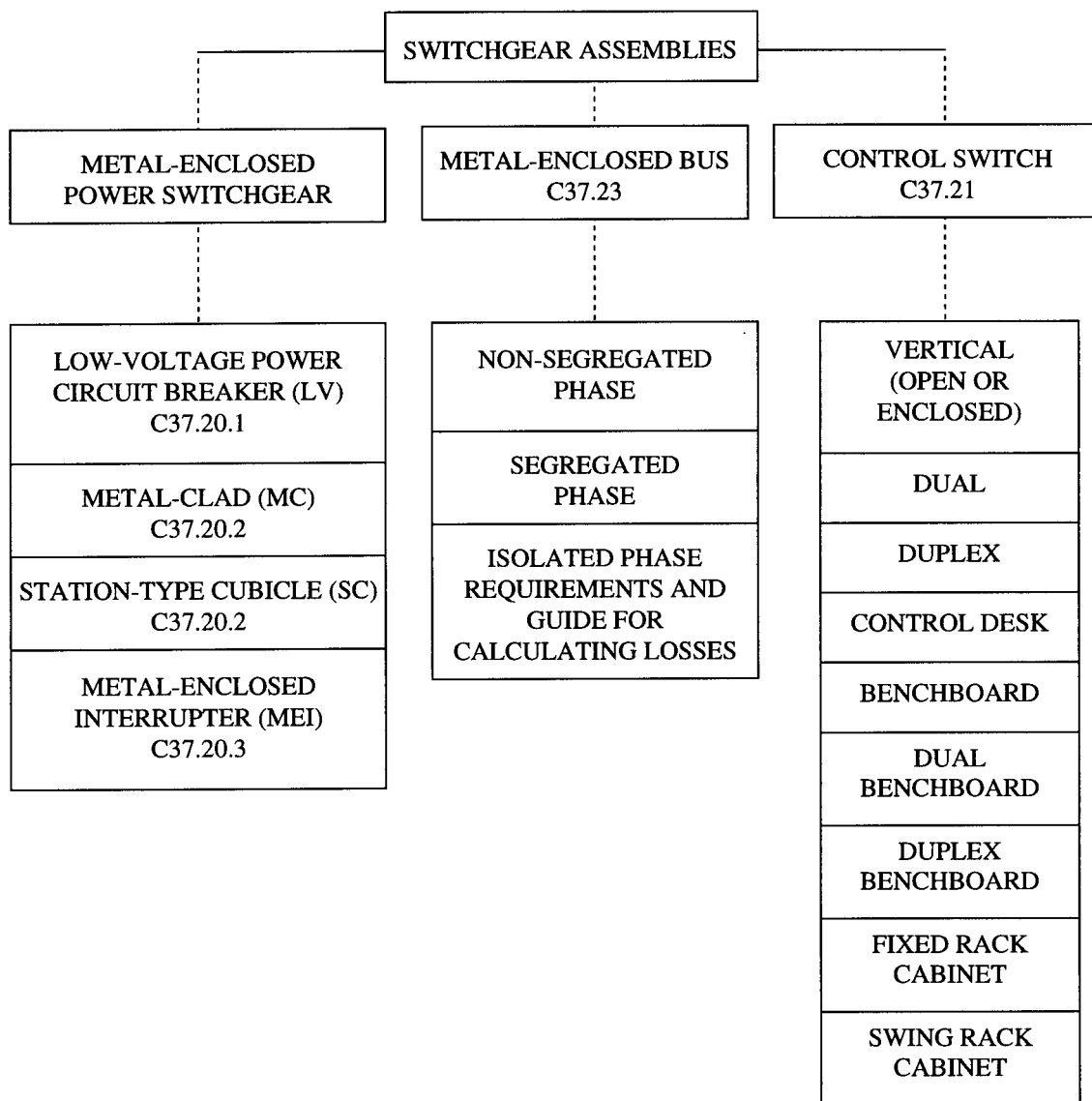


Figure A —Types of switchgear assemblies

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IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

1. Scope and references

1.1 Scope

This standard covers metal-enclosed low-voltage power circuit breaker switchgear assemblies containing, but not limited to, such devices as low-voltage power circuit breakers (fused or unfused); other interrupting devices; switches, control, instrumentation, and metering; and protective and regulating equipment.

This standard is concerned with enclosed, rather than open, indoor and outdoor switchgear assemblies. It includes types of equipment that are part of secondary unit substations. It does not apply to equipment covered by industrial control standards, communication switchboards, communication switching equipment, switchboards for use on board ships, or dead-front distribution switchboards.

In this standard, metal-enclosed low-voltage power circuit breaker switchgear shall be called LV switchgear. For ac LV switchgear, the voltage shall be 1000 V or below; for dc LV switchgear, the voltage shall be 3200 V or below.

1.2 References

This standard shall be used in conjunction with the following publications. When the standards referenced in this document are superseded by an approved revision, the revision shall apply.

Accredited Standards Committee C2-1993, National Electrical Safety Code (NESC).¹

ANSI C37.16-1988, American National Standard Preferred Ratings, Related Requirements and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors.²

¹The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ANSI C37.51-1989, American National Standard for Switchgear—Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies—Conformance Test Procedures.

ANSI/NFPA 70-1993, National Electrical Code.³

ANSI/UL 486A-1991, Wire Connectors and Soldering Lugs for Use With Copper Conductors.⁴

ANSI Z535.4-1991, American National Standard for Product Safety Signs and Labels.

ASTM B117-90, Standard Method of Salt Spray (Fog) Testing.⁵

ASTM D229-91, Standard Method of Testing Rigid Sheet and Plate Materials Used for Electrical Insulation.

ASTM D714-87, Standard Method for Evaluating Degree of Blistering of Paints.

ASTM D1535-89, Standard Method of Specifying Color by the Munsell System.

ASTM D1654-79a (R 1984), Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.

ASTM G21-90, Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.

IEEE Std 1-1986, IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation (ANSI).⁶

IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (ANSI).

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).

IEEE Std 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book) (ANSI).

IEEE Std 241-1990, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book) (ANSI).

IEEE Std 242-1986 (Reaff 1991), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book) (ANSI).

IEEE Std 344-1987, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (ANSI).

IEEE Std 446-1987, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book) (ANSI).

³The National Electrical Code is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Copies are also available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴ANSI/UL publications are available from Underwriters Laboratories Inc., Publication Stock, 333 Pfingsten Road, Northbrook, IL 60062. Copies are also available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁵ASTM publications are available from American Society for Testing and Materials, 1916 Race St, Philadelphia, PA 19103, USA.

⁶IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std C37.09-1979 (Reaff 1988), IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.2-1991, IEEE Standard Electrical Power System Device Function Numbers (ANSI).

IEEE Std C37.13-1990, IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures (ANSI).

IEEE Std C37.14-1992, IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures (ANSI).

IEEE Std C37.24-1986 (Reaff 1991), IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear (ANSI).

IEEE Std C37.26-1972 (Reaff 1976), IEEE Guide for Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits (ANSI).

IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear.

IEEE Std C37.90.1-1989, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI).

IEEE Std C37.90.2-1987, IEEE Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers (ANSI).

IEEE Std C57.13-1978 (Reaff 1986), IEEE Standard Requirements for Instrument Transformers (ANSI).

NEMA CC1-1993, Electric Power Connectors for Substations.⁷

NEMA WC5-1992/ICEA S-61-402, Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

NEMA WC7-1991/ICEA S-66-524, Cross-Linked Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

2. Definitions

The definitions of terms contained in this standard, or in other standards referred to in this standard, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.

If a term is not defined in this standard, the definition in IEEE Std C37.100-1992⁸ applies. An asterisk(*) following a definition indicates that the definition in this standard is not contained in IEEE Std C37.100-1992 while a dagger (†) indicates the definition differs from that in IEEE Std C37.100-1992 .

2.1 General

2.1.1 ambient air temperature: The temperature of the surrounding air that comes in contact with equipment.

NOTE — Ambient air temperature, as applied to enclosed switchgear assemblies, is the average temperature of the surrounding air that comes in contact with the enclosure. (See 5.2.2.3 for method of measurement.)

⁷NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037, USA.

⁸Information on references can be found in 1.2.

2.1.2 auxiliary compartment: That portion of the switchgear assembly that is assigned to the housing of auxiliary equipment, such as potential transformers, control power transformers, or other miscellaneous devices.*

2.1.3 circuit breaker compartment: That portion of a switchgear assembly that contains one circuit breaker and the associated primary conductors and secondary control connection devices including current transformers.*

2.1.4 conformance tests: Tests that demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned production tests prior to initiation of the conformance test program.†

NOTE — The conformance tests may, or may not, be similar to certain design tests. Demonstration of margin (capabilities) beyond the standards is not required.

2.1.5 design tests: Tests made by the manufacturer to determine the adequacy of the design of a particular type, style, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions if specified, and may be used to demonstrate compliance with applicable standards of the industry.†

NOTES:

1 — Design tests are made on representative apparatuses or prototypes to verify the validity of design analyses and calculation methods and to substantiate the ratings assigned to all other apparatuses of basically the same design. These tests are not intended to be made on every design variation or to be used as part of normal production. The applicable portion of these design tests may also be used to evaluate modifications of a previous design and to ensure that performance has not been adversely affected. Test data from previous similar designs may also be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

2 — *Design tests* are sometimes called *type tests*.

2.1.6 field tests: Tests made after the switchgear assembly has been installed at its place of utilization.

2.1.7 metal-enclosed low-voltage power circuit-breaker switchgear (LV): LV switchgear of multiple or individual enclosures, including the following equipment as required:

- a) Low-voltage power circuit breakers (fused or unfused) in accordance with IEEE Std C37.13-1990 .†
- b) Bare bus and connections
- c) Instrument and control power transformers
- d) Instruments, meters, and relays
- e) Control wiring and accessory devices

The low-voltage power circuit breakers are contained in individual grounded metal compartments and controlled either remotely or from the front of the enclosure. The circuit breakers may be stationary or removable (drawout) type; when of removable type, mechanical interlocks are provided for proper operating sequence.†

2.1.8 metal-enclosed power switchgear (ME): A switchgear assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors or removable covers, or both.†

2.1.9 production tests: Tests made for quality control by the manufacturer on every device or representative samples, or on parts or materials as required to verify during production that the product meets the design specifications and applicable standards.†

NOTES:

1 — Certain quality assurance tests on identified critical parts of repetitive high-production devices may be tested on a planned statistical sampling basis.

2 — *Production tests* are sometimes called *routine tests*.

2.1.10 switchgear: A general term covering switching and interrupting devices and their combination with associated control, instruments, metering, protective, and regulating devices; also assemblies of these devices with associated interconnections, accessories, and supporting structures used primarily in connection with the generation, transmission, distribution, and conversion of electric power.†

2.1.11 switchgear assembly (see figure A in the introduction): An assembled equipment (indoor or outdoor) including, but not limited to, one or more of the following categories: switching, interrupting, control, instrumentation, metering, protective, and regulating devices; together with their supporting structures, enclosures, conductors, electrical interconnections, and accessories.†

2.1.12 vertical section: That portion of the switchgear assembly between two successive vertical delineations, and may contain one or more circuit breakers, auxiliary compartments, and associated primary conductors.†

2.2 Qualifying terms

The following qualifying terms relating to types of enclosures, ventilation methods, etc., are defined in IEEE Std 100-1992 and the user is referred to the definitions given therein:

2.2.1 accessible (as applied to equipment):

2.2.2 alive (live):

2.2.3 automatic (self-coupling):

2.2.4 dead front:

2.2.5 enclosed (inclosed):

2.2.6 enclosed ventilated apparatus:

2.2.7 insulated:

2.2.8 insulating:

2.2.9 isolated:

2.2.10 manual:

2.2.11 ventilated:

The following qualifying terms are defined in IEEE Std C37.100-1992 and the user is referred to the definitions given therein:

2.2.12 electrical:

2.2.13 enclosure:

2.2.14 flame-resistant (retardant):

2.2.15 general-purpose enclosure:

2.2.16 indoor:

2.2.17 metal-enclosed:

2.2.18 outdoor:

2.2.19 resistant (used as a suffix):

2.2.20 secondary (used as an adjective):

2.2.21 ventilated enclosure:

2.3 Common or related terms

The following common or related terms are defined in IEEE Std C37.100-1992 and the user is referred to the definitions given therein:

- 2.3.1 asymmetrical:**
- 2.3.2 auxiliary switches:**
- 2.3.3 barrier:**
- 2.3.4 bus:**
- 2.3.5 connected position (of a switchgear assembly removable element):**
- 2.3.6 continuous current tests:**
- 2.3.7 current limiting fuse:**
- 2.3.8 disconnected position (of a switchgear assembly removable element):**
- 2.3.9 drawout-mounted device:**
- 2.3.10 ground bus:**
- 2.3.11 live parts:**
- 2.3.12 main (primary) switchgear connections:**
- 2.3.13 mimic bus:**
- 2.3.14 normal frequency:**
- 2.3.15 primary disconnecting devices (of a switchgear assembly):**
- 2.3.16 removable element (of a switchgear assembly):**
- 2.3.17 secondary and control wiring (small wiring):**
- 2.3.18 secondary disconnecting contacts:**
- 2.3.19 silver surfaced or equivalent:**
- 2.3.20 stationary-mounted device:**
- 2.3.21 symmetrical:**
- 2.3.22 terminal (terminal connector):**
- 2.3.23 terminal block (terminal board):**
- 2.3.24 test position:**

3. Service conditions

Standards for the design and performance of LV switchgear are based on usual service conditions as described below. The selection of equipment for a particular application can be based on the construction and ratings as defined in this standard provided that the following usual service conditions exist:

- a) The temperature of the cooling air (ambient air temperature) surrounding the enclosure of the LV switchgear is within the limits of $-30\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$.
- b) The altitude of the installation does not exceed 6600 ft (2000 m).
- c) The effect of solar radiation is not significant. (The principles stated in IEEE Std C37.24-1986 may be used for guidance.)
- d) Unusual service conditions, such as those outlined in 7.1, do not prevail.

4. Ratings

4.1 General

The ratings of a switchgear assembly are designations of operating limits under specified conditions of ambient temperature, temperature rise, etc. Where the switchgear assembly comprises a combination of primary and secondary circuits, each may be given ratings.

LV switchgear shall have the following ratings:

- a) Rated maximum voltage
- b) Rated frequency
- c) Rated insulation level
- d) Rated continuous current
- e) Rated short-time current
- f) Rated short-circuit current

The designated ratings in this standard are preferred but are not considered to be restrictive. In addition to these ratings, a switchgear assembly may have interrupting or switching capabilities, which are determined by the ratings of the particular interrupting and switching devices that are integral parts of the switchgear assembly. Refer to specific standards for the ratings of these devices.

Table 1— Voltage and insulation levels ac LV switchgear

Rated maximum voltage (rms)	Insulation levels (kV)	
	Normal frequency withstand (rms)	Reference * dc withstand
254/508/635	2.2	3.1

Table 2— Voltage and insulation levels dc LV switchgear⁹

Rated maximum voltage (rms)	Insulation levels dc LV switchgear (kV)	
	Normal frequency withstand (rms)	Reference * dc withstand
300/325	2.2	3.1
800 †	3.7	5.2
1200	4.6	6.5
1600	5.4	7.6
3200	8.8	12.4
NOTE — For field test values see 5.5.		

*The column headed “dc withstand” is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding normal frequency withstand test values specified for each voltage class of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac/dc equipment or that a dc withstand test represents an acceptable alternative to the normal frequency withstand tests specified in this standard, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of 1 min.

†See footnote 9.

⁹The values followed by a dagger (†) will be updated pending on the next revision. Refer to the table in 8.1 a) of IEEE Std C37.14-1992 for updated ac dielectric withstand voltage requirements.

4.2 Voltage and insulation levels

4.2.1 Rated maximum voltage

The rated maximum voltage of LV switchgear is the highest rms voltage for which the equipment is designed, and is the upper limit for operation.

4.2.2 Rated insulation level

The rated insulation level of LV switchgear is equal to the normal frequency one-minute withstand voltage.

4.2.3 Voltage and insulation levels for ac LV switchgear

The rated maximum voltages and corresponding insulation levels for ac LV switchgear are listed in table 1.

4.2.4 Voltage and insulation level for dc LV switchgear

The rated maximum voltages and corresponding insulation levels for dc LV switchgear are listed in table 2.

4.3 Rated frequency

The rated frequency of a device, or an assembly, is the frequency of the circuit at which it is designed to perform. (Ratings for ac equipment are based on a frequency of 60 Hz.)

4.4 Rated current

4.4.1 Rated continuous current

The rated continuous current of LV switchgear is the maximum current in rms amperes at rated frequency or direct current that can be carried continuously by the primary circuit components, including buses and connections, without causing temperatures in excess of specified limits for the following:

- a) Any primary or secondary circuit component
- b) Any insulating medium, or structural or enclosing member

The specified temperature limits applicable to switchgear assemblies are given in 4.5.1 through 4.5.6.

4.4.2 Continuous current ratings

The preferred continuous current ratings of the main bus in ac LV switchgear are 1600 A, 2000 A, 3000 A, 3200 A, or 4000 A. In dc LV switchgear the preferred continuous current ratings are 1600 A, 2000 A, 2500 A, 4000 A, 5000 A, 6000 A, 8000 A, 10,000 A, and 12,000 A.

The continuous current rating of the vertical section bus riser shall be equal to the frame size of the ac LV power circuit breaker used (see ANSI C37.16-1988) except as modified by the allowable cumulative loading of multiple ac circuit breakers in the same section (see table 13), or by lower continuous current ratings for current transformers, but in no case does it need to be greater than the rating of the main bus.

4.4.3 Rated short-time current

The rated short-time current of a LV switchgear assembly is the designated limit of available (prospective) current at which it shall be required to withstand its short-time current duty cycle (two periods of 1/2 s current flow, separated by