

A. I. E. E.
No. 13
May-1930

A. I. E. E. STANDARDS

Transformers, Induction Regulators and Reactors (Revised)



Published by
THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West Thirty-ninth Street, New York

Developments of the Standards of the American Institute of Electrical Engineers

Recognizing the importance in the development of electrical engineering, of standardization in the electrical field, the A. I. E. E. in 1898 appointed a Committee on Standardization, consisting of seven members having qualifications and experience from designing, manufacturing and operating standpoints. The report of this Committee was accepted at a meeting of the Institute in June 1899.

Experience gained in applications of the standards and further developments in electrical apparatus and methods showed the necessity of revision, and a committee was appointed which after consultation with manufacturing and operating engineers presented the first revised report on Standardization Rules of the A. I. E. E. in June 1902.

The next revision was undertaken by a committee of ten, which presented its report in May 1906.

In September 1906, a Standards Committee of eleven members was appointed for further revision, and its report was presented in June 1907.

The appreciation of the importance and value of standardization resulted in the formation of a Standing Committee, with the title of Standards Committee of the A. I. E. E. This became effective in the Constitution of June 1907. The scope and amount of work necessitated increasing the number of members from time to time until in 1922 there were 37 members divided into a number of subcommittees specializing on various subjects.

A. I. E. E. Standards published in a single volume as each revision was adopted have been generally accepted as Standards of the electrical industry of the United States since the adoption of the first report in 1899. Subsequent reports on Standards were made and published, in some cases in several editions. The dates of adoption by the Board of Directors of such reports are as follows: June 20, 1902; June 21, 1907; June 27, 1912; July 10, 1914; June 30, 1915; June 28, 1916; November 8, 1918; October 8, 1920, and June 29, 1922.

On June 29, 1922, in view of the increasing complexity of the work, a reorganization of the Standards Committee was effected, and a working organization established which provided for an increase in standardization work and for the appointment on Working Committees of the Standards Committee of non-Institute members.

The present plan under which the Institute Standards are being issued involves the separation of the complete body of Standards into more than forty sections, each published as a separate pamphlet and dealing with a specific subject. Each section of the Standards has been formulated either by a Working Committee of the Standards Committee which has been made as representative as possible for the work in hand or by a Sectional Committee organized according to the procedure of the American Standards Association. The division of the Standards into a number of separate publications simplifies the process of keeping the Standards revised to conform with the latest developments and enables those interested in a particular field to obtain in concise form the material relating to that field. In framing the Institute Standards the chief purpose has been to define terms and conditions which characterize the rating and behavior of electrical machinery and apparatus, with special reference to the conditions of acceptance tests.

The Standards Committee takes this occasion to draw attention to the value of suggestions based upon experience gained in the application of the Standards to general practise. Any suggestions looking toward improvement in the Standards will be welcomed for the guidance of the Committee in preparation of future editions, and should be communicated to the Secretary of the A. I. E. E. Standards Committee, 33 West 39th Street, New York.

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ACKNOWLEDGMENT

The Institute wishes to acknowledge its indebtedness to those who have so freely given their time and knowledge, and have conducted experimental work on which many of the A. I. E. E. Standards are based.

The following organizations, directly or through their committees, have given helpful cooperation in the development of this Standard.

The National Electrical Manufacturers Association

The National Electric Light Association

The A. I. E. E. Committee on Electrical Machinery

STANDARDS

OF THE

American Institute of Electrical Engineers

TRANSFORMERS, INDUCTION REGULATORS AND REACTORS

(Adopted by Board of Directors, August 6, 1925.)

Revised May 23, 1930 (See 13-1, 13-102, 13-140 to 145, 13-154, 13-215e, 13-250 to 252, 13-306, 13-307, 13-400, 13-401)

SCOPE

The standards in this section apply to:

- 13-1 Transformers.** (Exclusive of instrument transformers, auto transformers used as part of auto starters, rectifiers, special testing, series street lighting, sign lighting, ignition, and radio transformers and all small transformers used for special purposes.)

Standards for instrument transformers and for constant-current transformers are the subjects of separate sections.

- 13-2 Voltage Regulators.** (Exclusive of devices for controlling the voltage of generators).

- 13-3 Reactors.**

SERVICE CONDITIONS

- 13-50 Usual Service Conditions.**—Apparatus conforming with these standards shall be suitable for carrying their rated load:

- a. When and where the temperature of the cooling medium does not exceed 40 deg. cent. for air or 25 deg. cent. for water.
- b. Where the altitude does not exceed 1000 meters (3300 feet) when the cooling medium is air.

- 13-51 Limiting Observable Temperature of Oil.**—The oil in which apparatus is permanently immersed shall, in no part, have a temperature, observable by thermometer, in excess of 90 deg. cent.

- 13-52 Conditions Affecting Constructional or Protective Features.**—There are conditions which, while not usually affecting the rating, may require special consideration, principally with respect to constructional or protective features. Where such conditions exist it is recommended that they be brought to the manufacturer's attention. Among such conditions are:

- (a.) Exposure to damaging fumes.
- (b.) Operation in damp places.
- (c.) Exposure to excessive dust.
- (d.) Exposure to gritty dust.
- (e.) Exposure to steam.
- (f.) Exposure to excessive oil vapor.

- (g.) Exposure to explosive gases.
- (h.) Exposure to salt air.
- (i.) Exposure to abnormal vibration or shocks.

DEFINITIONS

Definitions given herein apply specifically to the apparatus treated in this section. They are included with all other standard definitions in a separate section.

Apparatus Classification

- 13-100 Transformer.**—A transformer is a form of stationary induction apparatus by means of which alternating electric energy, applied to one winding commonly called the primary winding, is transformed to alternating electric energy of the same frequency in another winding, commonly called the secondary winding, through the medium of electro-magnetic energy.

- 13-101 Auto Transformer.**—An auto-transformer is a form of transformer that has one continuous winding, part of which is common to both primary and secondary circuits.

- 13-102 Grounding Transformers.**—A grounding transformer is a transformer intended solely for the purpose of establishing a neutral ground connection.

- 13-103 Voltage Regulator.**—A voltage regulator is a form of transformer that has a primary winding in shunt and a secondary winding in series with the circuit, so arranged that the voltage ratio of transformation or the phase relation between the secondary voltage and the circuit voltage is variable at will.

- 13-104 Induction Voltage Regulator.**—An induction voltage regulator is a form of voltage regulator in which the relative position of the primary and secondary windings is adjustable by rotation.

- 13-105 Reactor.**—A reactor is a device used primarily because it possesses the property of reactance. Reactors are used in electric circuits for purposes of operation, protection or control.

Note: The term is commonly used to signify an inductive reactor.

13-106 Current Limiting Reactor.—A current limiting reactor is a form of reactor intended to limit the current that can flow in a circuit under short circuit.

Parts of Apparatus

13-107 High-Voltage and Low-Voltage Windings.—The terms "high voltage" and "low voltage" are used to distinguish the winding having the greater from that having the lesser voltage rating.

13-108 Primary and Secondary Windings.—The terms "primary" and "secondary" serve to distinguish the windings in regard to energy flow, the primary being that which receives the energy from the supply circuit and the secondary that which receives the energy by electro-magnetic induction from the primary.

13-109 Full Capacity Tap.—A full capacity tap is a tap from a transformer winding on which the transformer may be operated at the rated kv-a. capacity of the transformer without exceeding the specified temperature rise.

13-110 Reduced Capacity Tap.—A reduced capacity tap is a tap from a transformer winding on which the transformer may not be operated at the rated kv-a. capacity of the transformer without exceeding the specified temperature rise.

Properties of Apparatus

13-111 Rated Secondary Current of a Constant-Potential Transformer.—The rated secondary current of a constant-potential transformer is that secondary current which, multiplied by the rated secondary voltage, gives the rated kv-a. output.

13-112 Rated Primary Voltage of a Constant-Potential Transformer.—The rated primary voltage of a constant-potential transformer is the rated secondary voltage multiplied by the turn ratio.

13-113 Ratio of a Transformer.—The ratio of a transformer, unless otherwise specified is the "turn ratio;" *i. e.*, the ratio of the number of turns in the full high-voltage winding to that in the full low-voltage winding. In the case of transformers where taps are placed in one winding to give voltage variation in the other, the turn ratio is based on the number of turns corresponding to the minimum tap in the tapped winding.

13-114 Voltage Ratio of a Transformer.—The voltage ratio of a transformer is the ratio of the r. m. s. primary terminal voltage to the r. m. s. secondary terminal voltage, under specified conditions of load.

13-115 *Resistance Drop.—The resistance drop is the voltage drop in phase with the current.

13-116 *Reactance Drop.—The reactance drop is the voltage drop in quadrature with the current.

13-117 *Impedance Drop.—The impedance drop is the vector sum of the resistance drop and the reactance drop.

13-118 Regulation of a Constant Potential Transformer.—The regulation of a constant potential transformer is the difference between the no-load and rated-load values of the secondary terminal voltage, expressed in per cent of the rated load secondary voltage, with the primary impressed terminal voltage adjusted to such a value that the transformer delivers rated kv-a. output at a specified power factor and at rated secondary voltage.

13-119 Regulation of Induction Regulators.—The regulation of an induction regulator is the ratio, expressed in per cent, of the rated secondary voltage at rated kv-a. output to the rated primary voltage.

Systems

13-120 Rated Circuit Voltage.—In systems employing transformers, the rated voltage of the circuit is the highest rated voltage of the secondaries of transformers supplying the circuit. By "circuit voltage" is meant the voltage from line to line as distinguished from line to neutral. This voltage rating applies to all parts of the circuit. In the case of transformers having series multiple secondary connections the circuit voltage is determined by the series or the multiple connection as used.

Duty Classification

13-121 Continuous Duty.—Continuous duty is a requirement of service that demands operation at substantially constant load for an unlimited period.

13-122 Short-time Duty.—Short-time duty is a requirement of service that demands operation at a substantially constant load for a specific limited period.

13-123 Intermittent Duty.—Intermittent duty is a requirement of service that demands operation for alternate periods of load and rest.

13-124 Periodic Duty.—Periodic duty is a requirement of service that demands operation for alternate periods of load and rest in which the load conditions are well defined and recurrent as to magnitude, duration and character.

*For transformers the resistance drop, the reactance drop, and the impedance drop are respectively the sum of the primary and secondary drops reduced to the same terms. They are usually expressed in per cent of the secondary terminal voltage.

13-125 Varying Duty.—Varying duty is a requirement of service that demands operation at loads, and for periods of time which may be subject to wide variation.

Types

Combinations of the following types employing more than one of the methods of cooling described are frequently used.

13-140 Self-Cooled, Oil-Immersed Type.—A self-cooled, oil-immersed transformer is a transformer, the core and coils of which are immersed in oil, the cooling being obtained by natural circulation of air.

13-141 Water-cooled, Oil-Immersed Type.—A water-cooled, oil-immersed transformer is a transformer, the core and coils of which are immersed in oil, the cooling being obtained by the circulation of water through a coil installed in the transformer tank and immersed in the oil.

13-142 Forced Oil-cooled, Oil-immersed Type.—A forced oil-cooled, oil-immersed transformer is a transformer, the core and coils of which are immersed in oil, and the cooling of which is assisted by forced oil circulation through some external cooling means.

13-143 Air-Blast Type.—An air-blast transformer is a transformer cooled by a forced circulation of air through the core and coils.

13-144 Air-Cooled Type.—An air-cooled transformer is a transformer cooled by the natural circulation of air through the core and coils.

13-145 Forced Air-Cooled, Oil-Immersed Type.—A forced air-cooled, oil-immersed transformer is a transformer, the core and coils of which are immersed in oil, and the cooling of which is assisted by forced circulation of air.

RATING

13-150 Rating Defined.—A rating of a machine, apparatus or device is an arbitrary designation of an operating limit.*

For the purpose of this section of the standards the rating of a transformer or other induction apparatus is the output, together with any other characteristic such as voltage, current, frequency and power factor assigned to it by the maker. It shall be regarded as a test rating which defines an output, based on but not exceeding the maximum output which can be taken from the apparatus when tested in accordance with these standards.

The various kinds of rating recognized are:

*A rating is arbitrary in the sense that it must necessarily be established by definite fixed standards and cannot, therefore, indicate the safe operating limit under all conditions that may occur in service.

13-151 Continuous Rating.—The continuous rating defines the load which can be carried for an unlimited period, without causing any of the limitations established herein to be exceeded.

13-152 Nominal Rating of a Transformer.—The nominal rating of a transformer defines the constant load which, having been carried without causing further measurable increase in the temperature rise, may be increased 50 per cent for two hours without causing any of the limitations established herein for nominally rated transformers to be exceeded.

13-153 Short-Time Rating.—The short-time rating defines the load which can be carried for the time specified in the rating, the apparatus starting cold, without causing any of the limitations established herein to be exceeded.

13-154 Grounding Transformer Rating.—The rating of a grounding transformer defines its output during the time when one line is grounded.

13-155 Rating Implied.—In the absence of any specifications as to the kind of rating, the continuous rating shall be implied for all purposes except for transformers operating synchronous converters or motor-generator sets carrying traction loads where the nominal rating shall be implied.

13-156 Units in which Rating shall be Expressed.—

(a) *Transformers:* The rating of transformers shall be expressed in kv-a. output available at the secondary terminals at the rated voltage and frequency.

(b) *Induction Regulators:* The rating of induction regulators shall be expressed in kv-a. output at the rated frequency, secondary current and secondary voltage.

(c) *Current Limiting Reactors:* The rating of current limiting reactors shall be expressed in kilovolt-amperes absorbed at the rated current and frequency on a circuit of specified voltage rating.

13-157 Rating of Transformers having Taps.—Whenever a transformer is provided with taps from the windings it should be stated definitely whether they are full or reduced capacity taps. In the absence of such statement they are understood to be reduced capacity taps.

13-158 Single Voltage Rating.—A transformer having a single voltage rating is one which has two separate windings (primary and secondary), with only one voltage rating assigned to each.

13-159 Double Voltage Rating.—A transformer having a double voltage rating is one which has two separate windings (primary and secondary) with two voltage ratings assigned to each, the turn ratio being the same for both ratings.