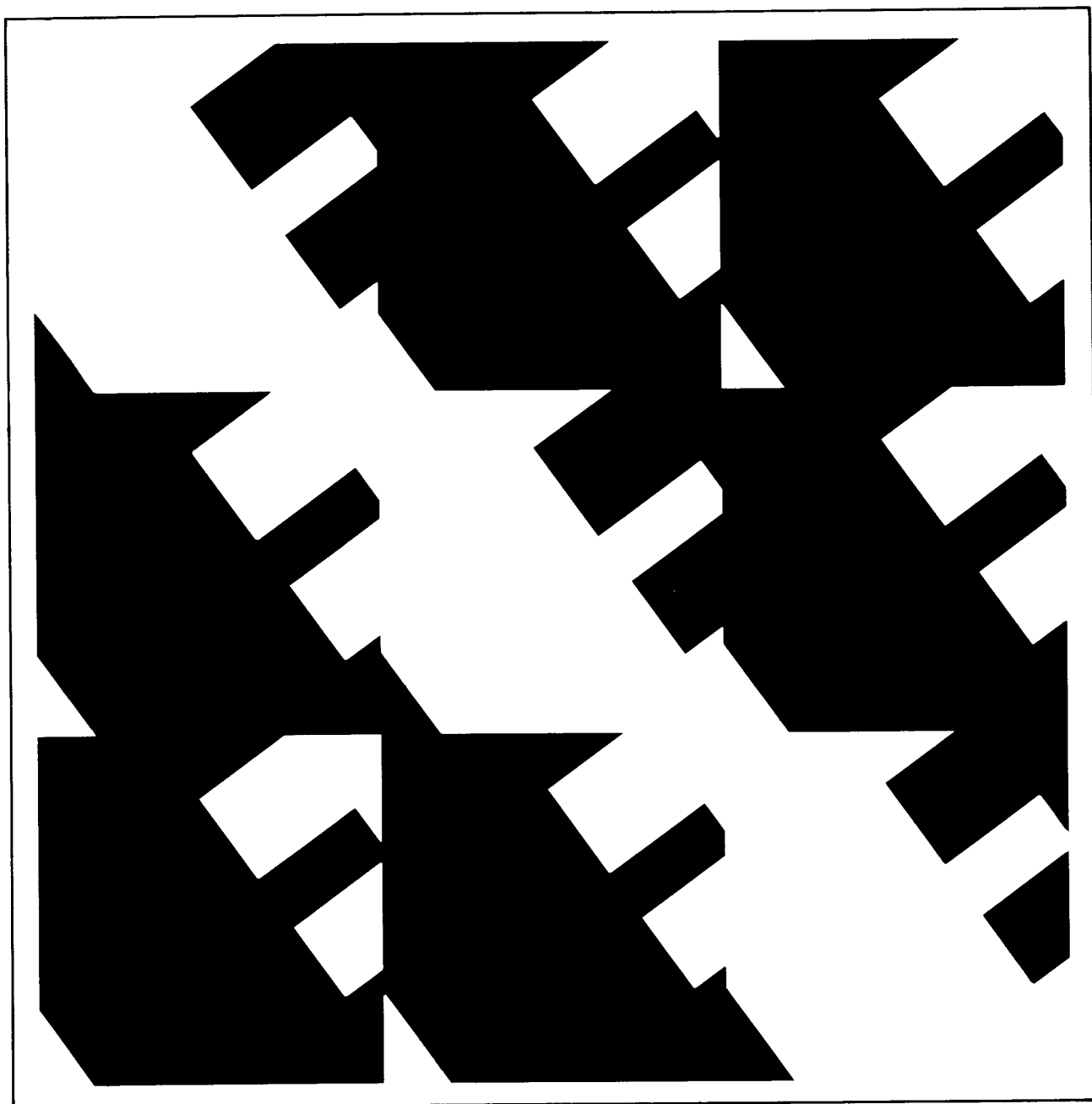


IEEE Recommended Practice for Efficiency Determination of Alternating-Current Adjustable-Speed Drives

Part I—Load Commutated Inverter Synchronous Motor Drives



ANSI/IEEE Std 995-1987



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An American National Standard

**IEEE Recommended Practice for
Efficiency Determination of Alternating-Current
Adjustable-Speed Drives**

Part I

Load Commutated Inverter Synchronous Motor Drives

Sponsor
**Industrial Drives Committee of the
IEEE Industry Applications Society**

Approved March 12, 1987
IEEE Standards Board

Approved September 11, 1987
American National Standards Institute

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Foreword

(This Foreword is not a part of ANSI/IEEE Std 995-1987, IEEE Recommended Practice for Efficiency Determination of Alternating-Current Adjustable-Speed Drives)

This recommended practice was prepared by the Industrial Drives Committee of the IEEE Industry Applications Society. Working Group P995 was established in 1983 to define a consistent method for determining and specifying the efficiency of large adjustable-speed alternating-current motor-drive systems.

The working group was divided into two groups designated P995.1 and P995.2 with assigned responsibilities for load commutated inverter synchronous motor drives and self-commutated inverter induction motor drives, respectively. The membership of the working group that prepared this recommended practice was as follows:

Herbert W. Weiss, *Chairman*

Nirmal K. Ghai
Leonard P. Gripp
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Thomas A. Higgins, Jr

James L. Kirtley, Jr
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Part I

Load Commutated Inverter Synchronous Motor Drives

1. Scope

This recommended practice proposes a method for determining the efficiency of large, adjustable-speed ac motor-drive systems consisting of a load commutated inverter and a synchronous machine, in which a dc-linked converter is connected between the line and the load.

This recommended practice is directed primarily to high-capacity systems (exceeding 1000 hp) and drive systems, which normally include equipments such as transformers, reactors, thyristor power converters, and synchronous machines. The drive system configurations, which are covered specifically in this recommended practice, are shown in Fig 1.

The method recommends that the existing test standards for the system equipments be used as reference, supplemented by test and calculations

included herein to account for operating characteristics of the adjustable-speed drive systems.

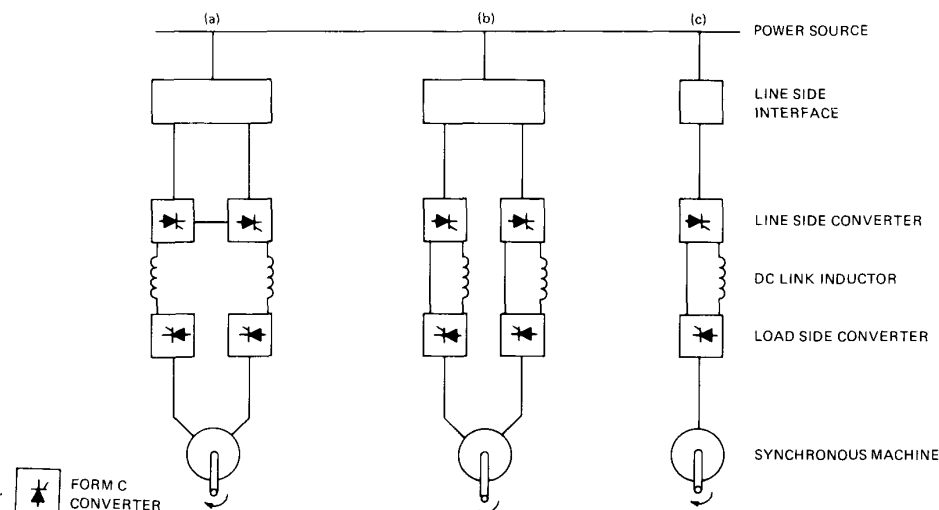
2. References

The standards listed below cover the definition of losses and efficiency, and the test methods for the equipments that are part of the adjustable-speed drive system. When approved revisions of the reference standards are issued, the revision should be used. This recommended practice should be used in conjunction with the following publications:

[1] ANSI C50.10-1977, American National Standard General Requirements for Synchronous Machines.¹

¹ ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

Fig 1
System Configurations (a) Single Channel System
(b) Dual Channel Parallel System (c) Dual Channel Series System



- [2] ANSI C57.16-1958 (R1971), American National Standard Requirements, Terminology, and Test Code for Current-Limiting Reactors.
- [3] ANSI/IEEE C57.12.00-1987, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers.²
- [4] ANSI/IEEE C57.12.01-1979, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers.
- [5] ANSI/IEEE C57.12.90-1987, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers.
- [6] ANSI/IEEE C57.12.91-1979, IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.
- [7] ANSI/IEEE C57.110-1986, IEEE Recommended Practice for Establishing Transformer Capability when Supplying Nonsinusoidal Load Currents.
- [8] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronic Terms.
- [9] ANSI/IEEE Std 115-1983, IEEE Guide: Test Procedures for Synchronous Machines.
- [10] ANSI/IEEE Std 444-1973, IEEE Standard Practices and Requirements for Thyristor Converters for Motor Drives Part I—Converters for DC Motor Armature Supplies.
- [11] ANSI/NEMA MG1-1978, Standards Publication for Motors and Generators.
- [12] FISCHER, J.D., So You Don't Think You Have a Harmonic Problem. Conference Record, 1979, *IEEE Industry and Applications Society Annual Meeting* (Power Systems Protection Committee), Table IV, 41D.

3. Definitions

3.1 Basic Terms

3.1.1 converter or converter equipment. An operative unit for electronic power conver-

² ANSI/IEEE publications are available from IEEE Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, or from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

sion, comprising one or more electronic switching devices and any associated components, such as transformers, filters, commutation aids, controls, and auxiliaries.

direct-current linked alternating-current converter. A converter comprising a rectifier and an inverter, with an intermediate dc link.

NOTES: (1) This definition is intended to include only those circuits in which the dc link is readily identified or explicit, and not those circuits having an implicit dc link but no single pair of conductors that can be identified as the dc link.

(2) For the purpose of this recommended practice the rectifier and inverter are **form C converter**.

externally commutated converter. A converter in which the commutating voltages are supplied by the ac supply lines, the ac load, or some other ac source outside the converter.

NOTE: For the purpose of this recommended practice, the term *converter* should be used.

form C converter. A single converter unit in which the direct current can flow in one direction only and which is capable of inverting energy from the load to the ac supply.

inverter. A converter for conversion from dc to ac.

NOTE: For the purpose of this recommended practice the *load side converter* normally operates as an inverter.

load commutated inverter. A converter in which the commutation voltages are supplied by the ac load.

NOTE: For the purpose of this recommended practice the ac load is a synchronous machine operating as a motor.

rectifier. A converter for conversion from ac to dc.

NOTE: For the purpose of this recommended practice the *line-side converter* normally operates as a rectifier.

3.1.2 convertor circuit elements (see Fig 2)

ac filter. Resistor-capacitor circuits connected in three-phase wye or delta on the ac terminals of a converter.

converter switching element. A part of

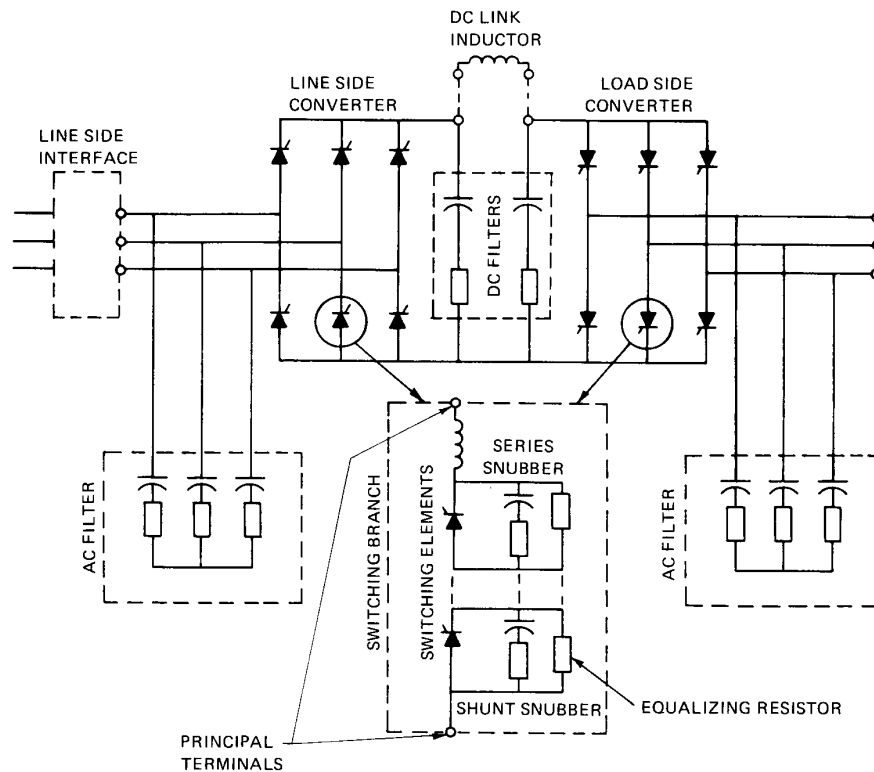


Fig 2
Converter Circuit Elements

the converter circuit, bounded by two principal terminals, containing one or more semiconductor devices having the property of controllable or noncontrollable conduction in at least one direction.

dc filter. A resistor-capacitor circuit connected between the positive and negative terminals of the dc link.

equalizing resistor. The resistor connected across the circuit element to equalize the off state voltage across elements that are connected in series.

principal branch (main branch). A branch involved in the major transfer of energy from one side of the converter to the other.

principal terminal. A terminal (of a device or circuit element) through which passes the current transmitting the power that is controlled by the device or circuit element. The term is used for distinction from control terminals, monitoring signal terminals, etc.

NOTE: Examples of principal terminals are the anode and cathode of thyristor or diode devices, the collector and emitter of bipolar transistor devices, and the source and drain of field-effect transistor devices.

snubber. An auxiliary circuit element or combination of elements employed to modify the transient voltage or current of a semiconductor device during switching.

(1) **shunt snubber.** Circuit elements, usually including a capacitor and a resistor connected in shunt with a switching device to limit the rate of rise of voltage

or the peak voltage across the device (or both) when switching from a conducting to a blocking state or when subjected to an external voltage transient.

(2) **series snubber.** Circuit elements, usually including an inductor, connected in series with a switching device to limit the rate of rise or fall of current through the device when switching on or off, respectively.

switching branch. A part of the circuit, including at least one switching element, bounded by two principal terminals.

NOTE: A switching branch may include one or more simultaneously conducting converter switching elements connected together, commutating reactor windings, and other devices intended to protect the semiconductor devices or to ensure their proper function, such as voltage and current dividers, and snubbers. In the simplest case, a switching branch may consist of only the switching element, which may be a single semiconductor device. The adjective *switching* may be omitted when the context of converter circuits is clear.

3.1.3 Circuit Properties

commutation. The transfer of current from one converter switching branch to another.

commutating voltage. The voltage that causes the current to commute from one switching branch to another.

NOTE: In an externally commutated converter, the commutating voltage is supplied by an ac source outside the converter.

3.2 Performance Characteristics

direct current. The time average value of the current in the dc link.

line-side converter alternating current. The magnitude of the current expressed in amperes of the rms value of current at the output terminals of the line-side interface and the input terminals of line-side converter.

Fig 3
Waveform Definitions

