ANSI C50.14-1977
(reaffirmed 1989)

American National Standard Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators

Secretariat

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American National Standard

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Foreword

(This Foreword is not a part of American National Standard Requirements for Combustion Gas Turbine Driven Synchronous Generators, C50.14-1977.)

Developed over a period of more than two years within a working group that reflected wide industrial experience in both the manufacture and use of Combustion Gas Turbine Generators, American National Standard C50.14-1977 received the unanimous approval of the C50.1 Subcommittee on Synchronous Machines as well as the full endorsement of American National Standards Committee C50 on Rotating Electrical Machinery.

It is the intent of C50 to revise and update this standard at regular intervals, and comments on this document, including recommendations for its revision, will be welcomed by the Committee. Please forward comments to the Secretary, American National Standards Committee C50, American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

At the time it approved this standard, American National Standards Committee C50 on Rotating Electrical Machinery had the following membership:

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CLAUSE PAGE

American National Standard Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators

1. Scope

The requirements in this standard apply to 60 Hz open-ventilated air-cooled cylindrical rotor synchronous generators rated 10,000 kVA and above.

All requirements and definitions, except as specifically covered in this standard, shall be in accordance with ANSI C50.10-1977 and C50.13-1977.

2. Classification

A combustion gas turbine driven synchronous generator is classified structurally as a cylindrical rotor synchronous generator, and with regard to cooling as indirectly cooled.

3. Usual Service Conditions

The power output of a combustion gas turbine, for a given combustion temperature, is a function of the density of the inlet air, which, in turn, is a function of temperature and atmospheric pressure. The standard operating condition for combustion gas turbines is 15°C inlet air temperature at sea level.

Combustion gas turbines usually carry several power ratings corresponding to different combustion temperatures. In general, these ratings are related to recommended turbine inspection and maintenance schedules. These various turbine output ratings are frequently grouped into three operating modes, namely, base, peak, and peak reserve. The latter two modes permit increased output with decreased intervals between turbine inspection and maintenance.

A generator driven by a combustion gas turbine and conforming to this standard shall be suitable for carrying load in accordance with the generator rating and capabilities under the following usual service conditions.

3.1 Inlet Air Temperature

The temperature of the inlet cooling air does not exceed 49°C (120°F) and is not less than –18°C (0°F).

3.2 Altitude

The altitude is sea level.

NOTE — The gas turbine power rating and the generator capability decrease at altitudes above sea level. The decrease in generator capability is less than the decrease in turbine rating.

3.3 Number of Starts

The starting frequency to substantial load conditions does not exceed 500 starts per year.

3.4 Application of Load

Load may be applied rapidly, and the rate of generator loading is limited only by the ability of the combustion gas turbine to assume load.

3.5 Variation from Rated Voltage

In addition to the preceding usual service conditions, generators shall operate successfully at rated kilovolt-amperes (kVA), frequency, and power factor at any voltage not more than 5 percent above or below rated voltage, but not necessarily in accordance with the standards of performance established for operation at rated voltage.

4. Output Rating and Capabilities

4.1 Output Rating

The generator continuous output rating shall be expressed in kilovolt-amperes available at the terminals at a specified speed, frequency, voltage, and power factor at an inlet air temperature of 15°C at sea level.

The output rating shall be equal to the generator base capability (defined in Section 4.2.1) at these conditions.

4.2 Capabilities

Generator capability is defined as the highest acceptable loading (kVA) at a specified condition. Typical generator capability curves are shown in Fig 1. In general, the power output-inlet air temperature characteristics of the generator and the combustion gas turbine do not have the same slope.

4.2.1 Base Capability

The manufacturer shall supply a curve showing generator continuous (8760 hours per year) base capability at rated power factor and sea level. The generator base capability should equal or exceed the base rating of the combustion gas turbine over a specified inlet air temperature range within the limits of Section 3.1.

4.2.2 Peak Capability

The manufacturer shall supply a curve showing generator peak capability at rated power factor and sea level. The generator peak capability should equal or exceed the peak rating of the combustion gas turbine over a specified inlet air temperature range within the limits of Section 3.1.

NOTE — Operation at peak capability will result in accelerated loss of life (see Section 5.2).

4.2.3 Peak Reserve Capability

The manufacturer shall supply a curve showing generator peak reserve capability at an increased power factor and sea level. The kilowatt output of the generator at peak reserve capability shall be obtained by increasing the power factor of the generator while maintaining the peak capability kilovolt-amperes. The generator peak reserve capability should equal or exceed the peak reserve rating of the combustion gas turbine over a specified inlet air temperature range within the limits of 3.1.

NOTE — Operation at peak reserve capability will result in accelerated loss of life (see Section 5.2).

4.2.4 Typical Generator Capability Curves

Typical curves are shown in Fig 1 as an illustration of the definitions of Section 4.

4.3 Voltage Ratings

4.3.1 Armature

Armature voltage ratings shall be the following:

6900*

11 500*

12 500*

13 800

14 400*

NOTE — Ratings followed by an asterisk (*) are recognized for use on established systems but not preferred for new undertakings.

4.3.2 Excitation System Voltage Ratings

The preferred excitation system voltage ratings for field windings are 125 and 250 direct voltage. These excitation system voltages do not apply to generators of the brushless type with direct connected exciters.

5. Temperature

5.1 At Output Rating

The observable temperature rise of each of the various parts of the generator, above the temperature of the inlet cooling air, shall not exceed the values given in Table 1. The temperature of the inlet cooling air is the temperature of the external air as it enters the ventilating openings of the generator, and the temperature rises given in the table are based on a maximum temperature of 15° C for this external air at sea level.

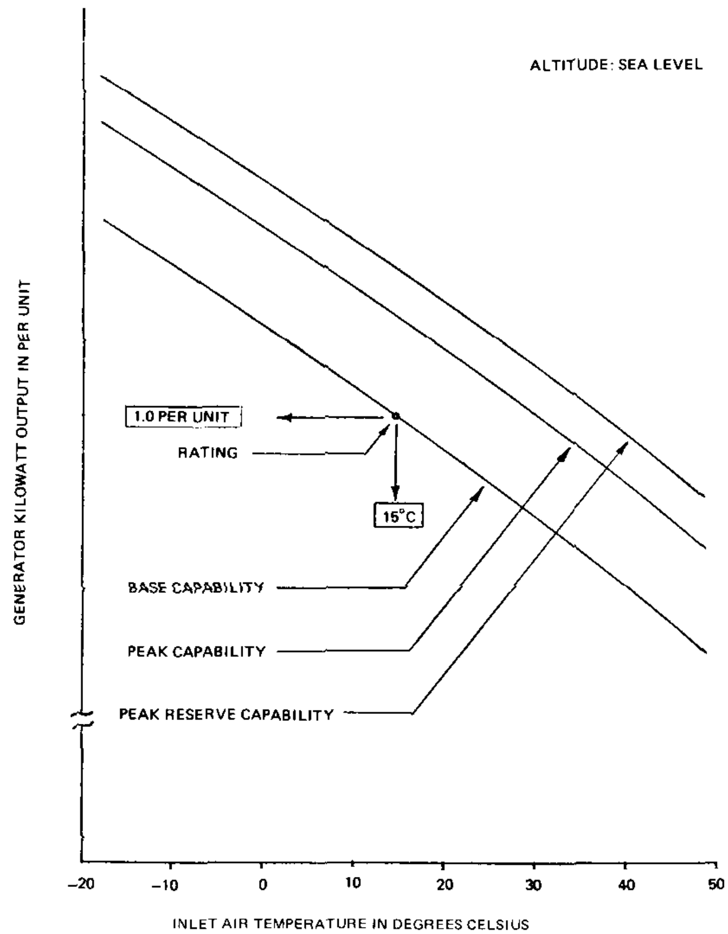

Figure 1—Typical Generator Capability Curves

When designing to meet the temperature rises of Table 1, it is intended that the hottest spot temperature should not exceed 130° C for Class B and 155° C for Class F insulation.

5.2 At Base, Peak, and Peak Reserve Capabilities

It is intended that the hottest spot temperatures of 130° C for Class B and 155° C for Class F insulation systems should not be exceeded at base capability. At peak and peak reserve capabilities, it is intended that the hottest spot temperatures of 155° C for Class B and 180° C for Class F insulation systems should not be exceeded. This design concept shall be demonstrable by direct measurement or recognized methods of calculation correlated to special factory tests on a basically similar machine.

The hottest spot temperatures for the peak and peak reserve capabilities are in excess of the usual 130° C value for Class B and 155° C value for Class F insulation systems.

Operation at these peak and peak reserve temperature values causes the generator insulation to age thermally at about 4 to 8 times the rate that occurs at the base capability temperature value, that is, operating 1 hour at peak or reserve temperature values is approximately equivalent to operating 4 to 8 hours at the base capability temperature values.

Table 1— Limiting Observable Temperature Rise* of Air-Cooled Combustion Gas Turbine Driven Cylindrical Rotor Generators

			Temperature Rise in Degrees Celsius at Output Rating	
			Insulation Class	
Item	Machine Part	Method of Temperature Determination	B	F
1	armature winding	embedded detector	95	115
2	field winding	resistance	110	130
3	cores and mechanical parts in contact with or adjacent to insulation	detector or thermometer	95	115
4	collector rings	thermometer	110	110
5	miscellaneous parts such as brush holders, brushes, etc		may attain such temperatures as will not injure the generator in any respect.	

*Temperature rises are based on a maximum inlet air temperature of 15°C at sea level.

6. Abnormal and Short-Circuit Requirements

6.1 Armature Winding Short-Time Thermal Requirements

The generator armature shall be capable of operating at 130 percent of rated armature current for at least 1 min starting from stabilized temperatures at rated conditions.

NOTES:

1 — The permissible armature currents at times up to 120 s based upon the same increment of heat storage as defined in 6.1, will be:

Time (seconds)	10	30	60	120
Armature current (percent)	226	154	130	116

2 — It is recognized that armature temperatures will exceed rated load values under these conditions and, therefore, the machine construction is based upon the assumption that the number of such operations at armature currents to the limits of Note (1) will occur not more than two times per year.

6.2 Field Winding Short-Time Thermal Requirements

The generator field winding shall be capable of operating at a field voltage of 125 percent of rated-load field voltage for at least 1 min starting from stabilized temperatures at rated conditions.

NOTES:

1 — The permissible field voltages at times up to 120 s, based upon the same increment of heat storage as defined in 6.2, will be:

Time (seconds)	10	30	60	120
Field voltage (percent)	208	146	125	112

2 — It is recognized that field winding temperatures under these conditions will exceed rated-load values and, therefore, the machine construction is based upon the assumption that the number of such operations at field voltages to the limits of Note (1) will occur not more than two times per year.

6.3 Rotor Short-Time Thermal Requirements for Unbalanced Faults

The generator rotor shall be capable of withstanding, without injury, unbalanced short circuits or other unbalanced conditions on the system or at the armature terminals resulting in values of $I_2^2\ t$ equal to or less than 30, where $(I_2^2\ t)$ is the integrated product of the square of the generator negative-phase-sequence current (I_2), expressed in per unit stator current at rated kVA and duration of the fault in seconds (t).

The generator unbalanced fault capability expressed in terms of $(I_2^2\ t)$ applies for times up to 120 s, based on a constant increment of heat storage and negligible heat dissipation.

In the above criteria, the generator shall be capable of withstanding the thermal effect of unbalanced faults, at the machine terminals, including the decaying effects of:

1) Field current, where protection is provided by causing field current reduction, such as with an exciter field breaker or equivalent.
2) DC component of the stator current.

NOTE — Generators, subjected to faults between the above value of $I_2^2\ t$ and 200 percent of this value, may suffer varying degrees of damage; for faults in excess of 200 percent of this value, serious damage may be expected.

6.4 Mechanical Requirements for Short Circuits

The generator shall be capable of withstanding, without mechanical injury,[1] any type of short circuit at its terminals for times not exceeding short-time thermal requirements, when operating at rated kVA and power factor and 5 percent overvoltage, provided the maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from the three-phase fault.

6.5 Continuous Unbalanced Requirements

A generator shall be capable of withstanding, without injury, the effects of a continuous current unbalance corresponding to a negative phase sequence current equal to or less than 10 percent of rated stator current, providing rated kVA is not exceeded, and the maximum current does not exceed 105 percent of rated in any phase.

This value also expresses the negative phase sequence current capability at reduced generator kVA capabilities in percent of the stator current corresponding to the reduced capability.

7. Efficiency

The following losses shall be included in determining efficiency:[2]

1) I^2R losses of armature and field winding.
2) Core loss.
3) Stray load loss.
4) Friction and windage loss.
5) Excitation systems losses, if required by specifications, shall include the exciter, voltage regulator, and associated devices comprising the excitation for a particular synchronous machine. Include motor loss if unit motor-generator, exciter set is used. If a unit rectifier is used, include the loss of the rectifier and rectifier transformer.

8. Overspeed

Cylindrical rotor generators shall be so constructed that they will withstand, without injury, an overspeed of 20 percent.

[1]In the case of stator windings, the criterion for no injury is that the windings can satisfactorily withstand a normal maintenance hipotential test. There shall also be no visible abnormal deformation or damage for the winding coils and connections.
[2]Refer to C50.10-1977 for definitions of losses.

9. Telephone Influence Factor

9.1 Balanced

The balanced telephone influence factor (TIF) of the generator, based on the weighting factors given in Section 9.3., shall not exceed the following values:

kVA Rating of Generator	Balanced TIF
10 000 to 19 999	100
20 000 to 99 999	70
100 000 and above	40

9.2 Residual

The residual component TIF of the generator, based on the weighting factors given in Section 9.3, shall not exceed the following:

kVA Rating of Generator	Residual TIF
10 000 to 19 999	75
20 000 to 99 999	50
100 000 and above	30

9.3 Single Frequency

The single frequency telephone influence weighting factors (TIF_f) according to the 1960 single frequency weighting are the following:

1960 Single Frequency TIF_f Weighting Factors

Frequency	TIF_f	Frequency	TIF_f
60	0.5	1860	7820
180	30	1980	8330
300	225	2100	8830
360	400	2160	9080
420	650	2220	9330
540	1320	2340	9840
660	2260	2460	10 340
720	2760	2580	10 600
780	3360	2820	10 210
900	4350	2940	9820
1000	5000	3000	9670
1020	5100	3180	8740
1080	5400	3300	8090
1140	5630	3540	6730
1260	6050	3660	6130
1380	6370	3900	4400
1440	6650	4020	3700
1500	6680	4260	2750
1620	6970	4880	2190
1740	7320	5000	810
1800	7570		

Methods of measurement for TIF shall be in accordance with IEEE Std 115-1965, Test Procedure for Synchronous Machines.

9.4 Other

Special consideration may be necessary where trouble exists or may be anticipated from difficult exposure conditions.

NOTE — (1) Although TIF is designed basically as a measure of the influence of current or voltage in a power circuit on parallel telephone circuits, the TIF of open-circuit generator voltage has been used for many years as an approximate index of the influence of generator wave shape. There has been no experience to indicate that generators designed in accordance with ANSI C50.1-1955 , Synchronous Generators, Synchronous Motors, and Synchronous Machines in General, have caused inductive coordination problems. However, accumulated measurements by manufacturers indicate that generator open-circuit TIF measured in accordance with the 1960 weighting averaged higher than with the 1935 weighting. Accordingly, in adopting the 1960 weighting in 1965, the limiting TIF values of lower capacity machines were increased. At the same time the greatly improved wave shape of modern high-capacity generators is recognized in setting a lower limit of balanced TIF for the larger units. (2) For information on TIF, see Supplement to Engineering Report 33, *The Telephone Influence Factor of Supply System Voltages and Currents,* Engineering Reports of the Joint Subcommittee on Development and Research, Edison Electric Institute and Bell System; Edison Electric Institute Publication 60-68. For further information on methods of measurement of TIF, see *Telephone Influence Factor (TIF) and Its Measurement,* W. C. Ball and C. K. Poarch, *AIEE Transactions,* Part I, vol 79, January 1961, pp 659-664 (Transactions Paper 60-1195).

10. Tests

Tests shall be as listed in Table 2. The tests shall be conducted in accordance with IEEE Std 115-1965 and ANSI C50.10-1977. The extent of the tests to be required in multiple unit orders should be mutually agreed upon by purchaser and manufacturer.

11. Direction of Rotation

The direction of rotation of the generator shall suit the prime mover requirements.

12. Nameplate Marking

A nameplate showing the manufacturer's name, serial number, or other suitable identification shall be provided. In addition, the following minimum information describing the rating shall be supplied:

1) Output kilovolt-amperes
2) Voltage
3) Revolutions per minute
4) Armature amperes
5) Frequency
6) Temperature rise of armature
7) Temperature rise of field
8) Number of phases
9) Power factor
10) Excitation voltage

Table 2—Tests on Combustion Gas Turbine Driven Cylindrical Rotor Generators

Tests	Generators Completely Assembled in Factory for Test	Generators Not Completely Assembled in Factory for Test	
	Factory Tests	Factory Tests	Field Tests
Resistance of armature and field windings	X*	X	X
Dielectric tests of armature and field windings	X	X	X
Voltage balance	X	—	X
Phase sequence	X	—	X
Mechanical balance	X†	X†	X†
Open-circuit saturation curve‡	X	—	X
Overspeed	X	X	—
Short-circuit saturation curve‡	—§	—	—§
Harmonic analysis and measurement of TIF	—§	—	—§
Heat runs	—§	—	—§
Short-circuit tests at reduced voltage to determine reactance and time constants	—§	—	—§
Measurement of segregated losses	—§	—	—
Measurement of rotor impedance	X	—	X
Measurement of insulation resistance of armature and field windings	X	—	X
Measurement of bearing insulation resistance	—**	—	X

*An X indicates that the test shall be made on each unit.
†A field check of mechanical balance of all generators is recommended after installation.
‡On brushless generators, readings of exciter field current instead of generator field current may be obtained.
§This test, or copies of a certified test report covering test made on an essentially duplicate generator, may be specified.
**On all generators furnished with one or more insulated bearings, a field measurement of the bearing insulation resistance is recommended.

11) Field amperes
12) Inlet air temperature
13) Altitude

NOTE — On generators furnished with brushless excitation systems, the exciter input rated voltage and current should be supplied for (10) and (11) respectively.

13. Performance Specification Form

Fig 2 shows the form which shall be used for specifying the performance of combustion gas turbine driven cylindrical rotor generators.

14. Revision of American National Standards Referred to in This Document

When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, the revision shall apply:

ANSI C50.10-1977, General Requirements for Synchronous Machines

ANSI C50.13-1977, Requirements for Cylindrical Rotor Synchronous Generators

The following data shall be given in accordance with ANSI C50.14-1977.

Date ____________

Output Rating

kVA	Power Factor	kW	Speed, r/min	No of Poles	No of Phases	Volts	Amperes	Type or Frame

Description: ____________

Type of excitation system: ____________

Amortisseur winding is (closed) (open) (not supplied)

Insulation Classes: Armature winding ________; Armature connections ______; Field Winding ________ .

Direction of rotation, viewing the end opposite the drive ________, if of unidirectional design or construction.

	Temperature Rise Guarantees			
		Rise(°C) Not To Exceed		
		Armature Winding		Field Winding
kVA	Power Factor	by Resistance	by Detector	by Resistance
		X		
Exciter (1)			X	

Maximum Excitation Requirements					
				Excitation System	
Generator Excitation		Exciter Input For Brushless Excitation		Response Ratio	Nominal Ceiling Volts
Amperes	Volts	Amperes	Volts		

(1) At "Maximum Excitation Requirements" operating level.

Rating and temperature rises are based on a maximum inlet air temperature of 15°C at sea level.

Efficiencies: When the generator is sold with the turbine as a set, generator efficiencies will be included in the overall set efficiencies. When sold as a generator only, efficiencies will be given below.

		Minimum Efficiencies						
				Percent Efficiencies				
kVA	Power Factor	kW		Rated Load	3/4 Load	1/2 Load		

In determining efficiencies, I^2R losses in the armature and field windings at ______ °C, open circuit core loss, and stray load loss are included. Friction and windage losses (are) (are not) included. Exciter and exciter-field rheostat losses (are) (are not) included. Generator-field rheostat loss is not included. If the generator is not furnished with a complete set of bearings, the friction and windage losses (if included) are based on the use of shop bearings.

Calculated Reactances (Per Unit At Rated kVA)				
Rated Current Direct Axis Synchronous Reactance, X_{di}	Rated Current Direct Axis Transient Reactance, X'_{di}	Rated Voltage Direct Axis Subtransient Reactance, X''_{dv}	Rotor Wk^2, $(lb\text{-}ft)^2$	Short Circuit Ratio

Approximate Weights in Pounds			
Total Net	Rotor Net	Heaviest Part for Crane	Total Shipping

Approximate Operating Data for Cooling System (at rated load):

a) Temperature of inlet water to bearing oil cooler, _____ °F, when required.
Volume of cooling water, _____ gallons per minute (gpm), for bearing oil cooler, when required.

b) Open ventilated, with external blower
Volume of cooling air, ______ cubic feet per minute (cfm)
Pressure drop through generator, ________ inches of water.

c) Open self-ventilated (no external blower)
Volume of cooling air, ________ cubic feet per minute (cfm)
Pressure drop available for external ducts, filters, etc., ________ inches of water when required.

Capabilities: Curve of kilowatt output versus inlet air temperature for

a) Base
b) Peak
c) Peak reserve at ______ power factor

Figure 2—Performance Specification Form for Combustion Gas Turbine Driven Cylindrical Rotor Generator

