AMERICAN NATIONAL STANDARD

Gas Turbine Control and Protection Systems

ANSI B133.4 - 1978

SECRETARIAT

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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United Engineering Center 345 East 47th Street New York, N. Y. 10017

FOREWORD

The purpose of the B133 standards is to provide criteria for the preparation of gas turbine procurement specifications. These standards will also be useful for response to such specifications.

The B133 standards provide essential information for the procurement of gas turbine power plants. They apply to open-cycle, closed-cycle, and semi-closed cycle gas turbines with conventional combustion systems for industrial, marine, and electric power applications. All auxiliaries needed for proper operation are covered. Not included are gas turbines applied to earth moving machines, agricultural and industrial-type tractors, automobiles, trucks, buses and aero-propulsion units.

For gas turbines using unconventional or special heat sources (such as: chemical processes, nuclear reactors, or furnaces for supercharged boilers), these standards may be used as a basis; but appropriate modifications may be necessary.

The intent of the B133 standards is to cover the normal requirements of the majority of applications, recognizing that economic trade-offs and reliability implications may differ in some applications. The user may desire to add, delete or modify the requirements in this standard to meet his specific needs, and he has the option of doing so in his own procurement specification.

As specified in the B133.4 standard, the gas turbine control system shall include sequencing, control, protection and operator information which shall provide for the orderly and safe startup of the gas turbine, control of proper loading and an orderly shutdown procedure. It shall include an emergency shutdown capability which can be operated automatically by suitable failure detectors or which can be operated manually. Coordination between gas turbine control and driven equipment must be provided for startup, operation and shutdown.

Suggestions for improvement of this standard will be welcome. They should be sent to The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

American National Standard B133.4 was approved by the B133 Standards Committee and final approval by the American National Standards Institute was granted on January 17, 1978.

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Procurement Standards For Gas Turbines

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AMERICAN NATIONAL STANDARD

GAS TURBINE CONTROL AND PROTECTION SYSTEMS

1. SCOPE

The intent of this Standard is to cover the normal requirements of the majority of applications, recognizing that economic trade-offs and reliability implications may differ in some applications. The user may desire to add, delete or modify the requirements in this standard to meet his specific needs, and he has the option of doing so in his own bid specification.

The gas turbine control system shall include sequencing, control, protection and operator information which shall provide for the orderly and safe start-up of the gas turbine, control of proper loading and an orderly shutdown procedure. It shall include an emergency shutdown capability which can be operated automatically by suitable failure detectors or which can be operated manually. Coordination between gas turbine control and driven equipment must be provided for startup, operation and shutdown.

2. CONTROL SYSTEM

2.1 Control Functions

2.1.1 Starting. The starting control system, including any prestart requirements, may be manual, semi-automatic or automatic as defined below:

(1) Manual start shall be provided upon mutual agreement of manufacturer and user. Manual start shall require the operator to start the auxiliary equipment; initiate, hold and advance the starting sequence (crank, purge, fire) and accelerate to minimum governor setting or ready for synchronizing in the case of generating sets.

(2) Semi-automatic sequence start may or may not require manual starting of the auxiliaries and shall permit the operator to commit the turbine by a single action to the complete starting sequence up to a minimum governor setting or ready for synchronizing in the case of generating sets.

(3) Automatic sequence starts require only a single action to start the required auxiliary equipment and initiate the complete starting sequence up to minimum governor setting or ready for synchronizing in the case of generating sets.

(4) The starting control system shall provide automatic purge period (whether the starting sequence is manual or automatic) of sufficient duration to permit the gas turbine to displace any combustibles from the inlet through the entire exhaust system, including the stack, before firing the unit. Depending on the fuel used or application, additional precautions may be necessary.

2.1.2 Loading. Loading of the set may be manual, semi-automatic or automatic up to a specified power level. Automatic loading may follow directly the starting sequence without requiring any additional action. In any mode of loading, periods of dwell at specific loads may be introduced to provide for warm-up requirements. When required by the application, the time from the start initiation to a specific load level or loading rates such as standard and emergency may be specified.

2.1.3 Shutdown. Shutdown may be normal or emergency. Consideration shall be given to the relationship of turbine controls to driven equipment. Except where otherwise specified, automatic means shall be provided for isolating upon shutdown the driven equipment from the system which it is supplying in order to prevent motoring or reverse flow. It may also be necessary to operate venting systems for the release of stored energy.

(1) *Normal Shutdown.* Normal shutdown shall follow an orderly, safe, step-by-step procedure based upon the requirements of the specific machinery and applications. This may be achieved by manual, semiautomatic or automatic means. Means shall be provided to permit restart.

(2) *Emergency Shutdown.* Emergency shutdown must be capable of manual operation and must also occur automatically as a result of automatic operation of plant protection devices. The system must cause the fuel shutoff valve to cut off the engine fuel supply. Normal shutdown sequence, as appropriate, should subsequently take place. Where practical, means shall be provided to prevent restart without corrective action.

2.2 Fuel Control

The fuel delivered to the prime mover must be controlled throughout the operating regime, from initial light-off to maximum conditions as well as all accelerations and decelerations.

The degree of control and the accuracy of maintaining a set point are a function of the specific application and should be specified in detail in procurement documents.

2.2.1 Steady State Speed Regulation. Steady state speed regulation or droop shall be capable of adjustment within the range of 2 to 6% at rated speed.

2.2.2 Constant Speed. Gas turbines which are to be regulated to a substantially constant speed (in particular those driving electric generators), shall be fitted with a governor sensing the output shaft speed. Unless otherwise agreed between the user and manufacturer, the speed changer shall be capable of adjusting the turbine speed, while the turbine is operating at zero output, to any value between 95 and 106% of rated speed.

With the generator synchronized to the grid, the speed changer of the gas turbine fuel control shall be capable of reducing the output from maximum unit rated output to zero in an operating time specified by the user to be compatible with other speed changers on units running in parallel.

2.2.3 Variable Speed. For gas turbines which are required to operate over a range of speeds, such as with mechanical drives, suitable control equipment should be provided. The speed range should be specified by the user.

2.2.4 Isochronous Control. The speed governing system shall be capable of isochronous speed control if required by the user.

2.3 Performance Requirements

2.3.1 Deadband. The deadband at rated speed and at any power output up to and including the maximum power output shall not exceed 0.1% of the rated speed. However, for large output generator applications the deadband will be expected to be generally lower.

2.3.2 Drift. Drift limitation of any control mode should be agreed upon between manufacturer and user.

2.3.3 Stability of the Speed Governing System

(1) The speed governing and fuel control systems, with the turbine operating between zero and maximum load, shall be capable of stable control of:

(a) The speed of the turbine when the driven equipment is operated isolated.

(b) The fuel energy input to the turbine when the driven equipment is operating in parallel with other driven equipment.

In certain cases, the control is obtained by a combination of (a) and (b) above. Stability of operation is also required in these cases.

(2) The speed governing and fuel control systems shall be considered stable when:

(a) The driven equipment is operated isolated and under sustained load demand, and the magnitude of the sustained oscillations of turbine speed produced by the speed governing system and fuel control system does not exceed a peak-to-peak amplitude of 0.24% of the rate speed (ISO DIS 3977). State-of-the-art control systems can be expected to be stable with a peak-to-peak amplitude of 0.12% of rated speed or less.

(b) The driven equipment is operated at rated speed in parallel with other driven equipment at constant speed and the magnitude of the sustained oscillations of energy input produced by the speed governing system and fuel control system does not produce a change in output exceeding a peak-to-peak amplitude of 4% of the rated output (ISO DIS 3977). State-of-the-art control systems can be expected to be stable with a peak-to-peak amplitude of less than 3% of rated output.

For gas turbines of large output, the permissible magnitude of oscillations is expected to be generally lower.

2.3.4 Stability of the Temperature Control System. The temperature control and fuel control systems shall be capable of controlling with stability the temperatures of the gas turbine when the turbine is operating on temperature control at the maximum limit for the ambient condition existing.

The temperature limiting or control system and fuel control system shall be considered stable provided the magnitude of the sustained oscillation of turbine fuel energy input produced by them does not produce a change in output exceeding a peak-to-peak amplitude of 6% of rated output (ISO DIS 3977). State-of-the-art control systems can be expected to be stable with less than a peak-to-peak amplitude of 4% of rated output.

2.3.5 Stability of a Kilowatt Control System. For generator applications, the kilowatt control and fuel control systems shall be capable of controlling with stability the kilowatt loading when the gas turbine is operating on kilowatt control on a constant frequency bus.

The kilowatt control and fuel control system shall be considered stable provided the magnitude of sustained oscillation of turbine fuel energy input produced by them does not produce a change in output exceeding a peak-to-peak amplitude of 4% of rated output. State-of-the-art control systems can be expected to be stable with a peak-to-peak amplitude of less than 3% of rated output.

2.3.6 Stability of a Mechanical Drive Control System. For gas turbine mechanical drive applications, the fuel control system shall be capable of controlling with stability the gas turbine output power.

The fuel control system shall be considered stable when with steady load conditions, the magnitude of sustained oscillation of turbine fuel energy input produced by it does not produce a change in output power exceeding a peak-to-peak amplitude of 4% of rated power. State-of-the-art control systems can be expected to be stable with a peak-to-peak amplitude of less than 3% of rated output.

2.3.7 Overall System Stability. In certain installations where the driven equipment and its associated system exercises an overriding influence, the criteria of stability in the above paragraphs may not be achievable.

2.3.8 Transient High Speed Limits. Unless otherwise agreed upon by the user, governor systems shall prevent the gas turbine from reaching the turbine trip speed with an instantaneous loss of load up to rated load unless such a loss of load is not a practical condition.

It is recognized that the speed transients are a function not only of governor performance, but also of the gas turbine characteristics, the inertia of the rotating mass and magnitude of load transients possible.

2.3.9 Output Power Limiting. Consideration shall be given to the need for preventing excessive shaft output power by means such as lowering the turbine limiting temperature as a function of decreasing ambient temperature. Other means may be used such as sensing output power or gas producer speed as a control parameter.

2.4 Wiring

Consideration shall be given to wiring methods in order to minimize operating problems. This includes wire routing, shielding, high machine temperatures, vibration, separation of control, instrumentation, and power leads as well as terminal connections, terminal and wire markings and circuit protection.

3. PROTECTION SYSTEM

3.1 Protection Requirements

3.1.1 Fuel Shutoff. In addition to the fuel governor valve, the fuel control system shall include a separate fast acting shutoff valve or "stop valve" which stops all fuel flow to the turbine on any shutdown condition, and which will not open until all permissive firing conditions are satisfied.

The risk from fuel leakage into the gas turbine after shutdown shall be minimized by means such as use of vent valves or redundant positive shutoff valves.

3.1.2 Overspeed Protection. An overspeed trip shall be provided to operate at a level which will not allow the transient speed to exceed the maximum safe limit for the line of shafting or other driven equipment under any sudden loss of load. Its main function is the cut off of fuel by means independent of the main governor.

In a gas turbine system, particularly with multi-shaft units, where coupled equipment may be subjected to high acceleration on loss of load, speed may continue to rise after the operation of the overspeed