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**Power Plant Control System
Dynamic Performance Test Methods
and Procedures**

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Power Plant Control System Dynamic Performance Test Methods and Procedures

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Foreword

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Abstract

This technical report defines test procedures, data collection requirements, performance metrics, and data analysis methods for determining and reporting the dynamic performance of control systems for boiler and turbine control systems on generating units. While specific test plans are not provided, a recommended outline for a test plan is included. This technical report covers aspects of dynamic plant operation including constant load operation, normal load ramping operation, grid regulation operation, and response to frequency upset, load runback, and load rundown operation.

Key Words

Control system, control system performance, control system testing, dynamic performance, power plants, test plan, performance testing.

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1 Scope

This technical report defines test procedures, data collection requirements and data analysis methods for determining and reporting the dynamic performance of control systems for boiler and turbine control systems on generating units with a rated capacity of 25 MW or greater or a boiler steam flow greater than 25 kg/s (200,000 lb/hr). This technical report covers aspects of dynamic plant operation including constant load operation, normal load ramping operation, grid regulation operation, and response to frequency upset, load runback, and load rundown operation.

2 Purpose

The purpose of this technical report is to establish dynamic performance criteria for power plant control systems by specifying a consistent means of evaluating control system performance necessary to comply with contractual specifications and other dynamic performance requirements.

3 Definitions

3.1 actuator

a field device that receives the controller output signal as a reference and changes the position of a final control element accordingly through pneumatic, electro-mechanical, or hydraulic means

3.2 adaptive tuning

see gain scheduling

3.3 boiler follow mode

a mode of boiler control where the boiler responds to an energy demand requirement and controls boiler pressure by regulating boiler inputs (from ANSI/ISA-77.43.01-2014)

3.4 calculated value

a virtual process variable that is derived from one or more measurements or other variables. Examples include process variables that have density compensation, median selection, averaging, etc.

3.5 composed point

see calculated value

3.6 controllable parameters

the set of all the process variables in a control system

3.7 controlled variable

see process variable

3.8 controller output

also called the manipulated variable, this is the signal from a controller that positions a final control element in the field or sets the setpoint of another controller

3.9 coordinated mode

a mode of boiler/turbine control that provides for the parallel operation of the boiler and the turbine as a unit to match generation to demand while maintaining boiler/turbine balance (from ANSI/ISA-77.43.01-2014)

3.10 deadtime

the elapsed time from a change in a manipulated variable until the start of a change in the associated process variable. Also called delay time.

3.11 delay time

see deadtime

3.12 desired value

see setpoint

3.13 deviation

see loop error

3.14 disturbance

a condition in the process or environment that tends to move the process variable from its setpoint

3.15 disturbance rejection

a control system design objective which aims to minimize the effect of disturbances on the process variable

3.16 error

see loop error

3.17 error deadband

a control technique in which the error signal used for control is considered to be zero when the process variable is within one deadband from the setpoint. When the loop error exceeds the deadband, the error signal used for control will be one deadband less than the actual loop error. Deadband is applied to reduce the effect of measurement noise on the control loop.

3.18 feedforward (control)

an open loop control strategy in which a measured or calculated disturbance signal is used to produce a control action to counteract and reduce the disturbance effect

3.19 filter, filtering

the removal of unwanted frequency components of a signal

3.20 final control element

component of a control system (such as a control valve) that directly regulates the flow of energy or material to or from the process

3.21 gain scheduling

also called adaptive tuning, this is a technique in which the controller gain is adjusted to compensate for changes in process gain. A controller's integral and derivative settings can also be adjusted to compensate for changes in process dynamic response. The latter is also referred to as gain scheduling.

3.22 integral squared error

control loop performance metric which is the integral (summation) of the square of the loop error signal over a time frame of interest, generally following a prescribed loop disturbance such as a setpoint step change

3.23 integral time absolute error

control loop performance metric which is the integral (summation) of the product of time and the absolute value of the loop error signal over a time frame of interest, generally following a prescribed loop disturbance such as a setpoint step change

3.24 loop deviation

see loop error

3.25 loop error

the difference between the loop setpoint and the process variable

3.26 loop error difference block

the algorithm (block) used for calculating the difference between the process variable and its setpoint

3.27 manipulated variable

see controller output

3.28 noise

a characteristic of process-variable signals evidenced as rapid, short-term deviations from the average

3.29 oscillation

a persistent swing between a high value and a low value of a process variable

3.30 overshoot

a characteristic of a process variable's response in which the variable temporarily exceeds the desired value before stabilizing at the final value. Overshoot is generally expressed as a percentage of the change in the setpoint and is generally an undesirable characteristic.

3.31 process variable

also called the controlled variable or measured variable, this is a measured, calculated, or inferred property of the process that becomes the feedback signal for closed-loop control

3.32 pseudo-random binary sequence (PRBS)

a signal used to excite a system generally for the purpose of producing response data which can be used to identify a model of the system. The signal steps up and down between two fixed values and the timing of the steps is a nearly random sequence.

3.33 primary frequency response

the automatic, frequency-driven, rapid governor response of generated power to oppose grid frequency changes. In this case, a "rapid" response is one that starts within a few seconds and is fully achieved within about 30 seconds.

3.34 reference

see setpoint

3.35 rise time

a control response metric for a setpoint step change test which is the time from when the response crosses 10% of its desired change until it crosses 90% of its desired change

3.36 secondary frequency response

the automatic, frequency-driven response of generated power applied following a primary frequency response where the secondary response typically has a larger magnitude and longer sustained period

3.37 setpoint

the desired operating value of the process variable

3.38 sliding pressure operation

a boiler control mode in which the boiler outlet pressure setpoint is varied as a function of the load on the boiler

3.39 step test

a test during which the controller output is changed by a few percent to determine the dynamic characteristics of the process it is controlling

3.40 turbine follow mode

a mode of turbine control in which the turbine inlet valves are manipulated to regulate the pressure upstream of the turbine inlet valves

3.41 variable pressure operation

a boiler control mode in which the boiler outlet pressure setpoint is varied as a function of time

3.42 valves wide open (VWO)

a turbine operating point in which the turbine inlet regulating valves are fully open

4 Abbreviations (Acronyms)

ISE: integral of the square of the error

ITAE: integral of time and absolute error

MV: manipulated variable

OPC: object linking and embedding for process control

PRBS: pseudo-random binary sequence

PV: process variable

SP: setpoint

5 Introduction

Many electric generating power plants must change load frequently to match the varying load demand of electricity users. Since there is very little electricity storage capability in the electric system, the total power generated must match the total power consumed on a minute by minute basis. Modern power plants have sophisticated automatic control systems which enable the plants to change load with little or no assistance from the plant operator. It is important that the plant respond to load changes and other disturbances in a stable and timely manner to minimize plant transients and provide the required power when needed by the power system. The plant response is determined by both the inherent design of the plant and by the capability of the plant's control system.

The importance and value of a plant's dynamic response has varied over the years depending on the excess capacity available at the time and has also varied by regions depending on the size of the power system. In recent years the addition of significant renewable generating sources such as wind turbines and solar photovoltaics has increased the need for conventional power plants to respond more quickly to the random fluctuation in output from the renewable sources. In competitive electric markets, the capability to respond to remote generation control signals is a valuable commodity which can be sold to the power system operator. Plant dynamic response is also important during power system disturbances such as major transmission line outages, system islanding, and blackouts. During such conditions, the plant must be capable of responding to system frequency upsets to help maintain the proper balance in a region between the power generated and the power being consumed. If system frequency is not tightly controlled it will lead to unit trips and possibly larger outages.

Because plant dynamic response is an important aspect of every power plant control system, many users and suppliers perform dynamic response tests on plants to quantify the actual dynamic response of the plant. Until now there has not been an industry standard procedure or guidance for conducting these tests. This technical report provides guidance and recommended procedures for conducting dynamic response tests on several types of conventional power plants. Plant control system engineers, control system suppliers, engineering firms, independent system operators, and other professionals interested in power plant dynamic response can use this technical report to construct test plans considering the supplier's control strategies designed to meet the operating mission of the customer's plant. The report may also be referenced in control system procurement specifications for acceptance testing. It will also be useful for anyone performing control system tuning as a way of quantifying and documenting the change in plant response before and after the tuning is completed.

6 Test management

Conducting power plant control system dynamic performance tests is a complex task involving several different groups within the power company and possibly other external organizations.

To ensure the tests are conducted effectively with minimal impact on the plant operation and grid stability, a test plan is required for guiding the test and communicating testing plans to others. The following steps should be followed to ensure the test is planned and communicated in a proper way.

1. Establish performance test team
2. Prepare a high-level test plan including:
 - a. Name and contact details of the test team leader and other key team members
 - b. Purpose of test
 - c. Test outline (e.g., target unit, start load, ramp rate, end load, additional ramps, etc.)
 - d. Preliminary date and time for test execution
 - e. Personnel requirements (plant staff, central test group, system supplier, etc.)
 - f. Any specific plant requirements (e.g., all mills available, coal bunkers filled with a single source of coal)
3. Communicate the high-level test plan to all the affected departments (Operations, I&C, Production Planning, etc.) and solicit inputs. Revise the test plan if necessary.
4. Obtain permission from plant management for conducting the test.
5. Obtain permission from dispatch for conducting the test.
6. Distribute final test plan including schedule to all parties.

6.1 Performance test team

A performance test team should be established with representation from all involved parties to ensure good communication and coordination throughout the test planning and execution. The composition of the performance test team will depend on many factors such as the scope of the test, the purpose of the test, the organization of the operating company, and how the unit is dispatched. Potential members of the performance test team include representatives or liaisons from:

1. Plant Management
2. Plant Operations Management
3. Unit Operations (one unit operator)
4. Plant Engineering
5. Control Technicians
6. Central Engineering
7. Control System Vendor