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An Integrated Approach to Strategic Management of a Cogeneration Facility

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INTRODUCTION

Obtaining the maximum possible return on investment is a primary objective of any cogeneration plant owner. Truly achieving this objective requires a strategic process management approach to the operation of a cogeneration facility as described herein.

STRATEGIC COGENERATION MANAGEMENT

Strategic process management of a cogeneration plant is distinguished from traditional process control in that process control is the component that serves to implement economic decisions made at the higher levels of the strategic process management system. It is helpful to view strategic process management in a hierarchical manner, as shown in Figure 1. There are five levels to the functional hierarchy: (1) Base Regulatory and Sequential Process Control and Data Acquisition, (2) Performance Assessment, (3) Human Interface, (4) Supervisory Control, and (5) Plant Optimization. Each level of the hierarchy must be successfully implemented before the next higher level can be achieved.

LEVEL ONE - BASE REGULATORY AND SEQUENTIAL PROCESS CONTROL AND DATA ACQUISITION

Process information enters the Strategic Cogeneration Management System at the Base Regulatory and Sequential Process Control and Data Acquisition level. Analog and digital input signals generated from field-mounted sensors are used in the control strategy to determine the appropriate output signals for valve positioning, motor start/stops, etc., as well as being processed for use in other levels of the hierarchy.

The Base Regulatory and Sequential Control and Data Acquisition level for a combined cycle cogeneration plant is comprised of four operational segments. The four segments and their primary functions are as follows:

1. Gas Turbine-Generator Segment

   A. Start-Up Sequencing and Fuel Control

      - Pre-start condition monitoring
      - Starting motor control
      - Fuel scheduling control
      - Fuel flow limiting
      - Vibration monitoring
      - Bearing metal temperature monitoring
      - Fuel pump pressure control
      - Speed control (droop or isochronous)
      - Load control
      - Inlet guide vane control
      - Generator and exciter monitoring

B. Temperature Control

- o Blade path temperature monitor
- o Exhaust temperature monitor
- o Temperature control from base load to peak load

C. Surge and Speed Monitoring and Protection

- o Speed measurement
- o Overspeed protection
- o Load rejection anticipation
- o Load imbalance control
- o Compressor surge control

2. HRSG/BOP Segment

A. Feedwater/Drum Level Control

B. Steam Temperature Control

C. Duct Burner Control

D. Deaerator and Water Treatment System Control

E. Bypass Damper Control

F. BOP Pump Controls

G. Cooling Water Temperature Control

3. Steam Turbine Segment

A. Speed Control

- o Speed setpoint and acceleration rate selection
- o Automatic synchronizer mode

B. Load Control

- o Initial megawatt loading
- o Load setpoint and rate selection
- o Throttle pressure regulation
- o Frequency correction

C. Overspeed Protection

D. Vibration Monitoring

4. Auxiliary Boiler Segment

   A. Feedwater/Drum Level Control

   B. Steam Temperature Control

   C. Combustion Control with Excess Air Trim

   D. Furnace Draft

   E. Deaerator and Water Treatment System Control

   F. Blowdown Control

   G. Burner Management

LEVEL TWO - PERFORMANCE ASSESSMENT

The Performance Assessment level of the Strategic Cogeneration Management System quantifies the performance of the cogeneration plant by assessing each major component relative to a performance model for that component. Performance models for each component are based on theoretical analysis of the component's performance through mass and energy balances; empirical coefficients for the models are determined automatically on-line during start-up, using data gathered under all operating modes and applying regression analysis techniques.[1]

As shown on Figure 2, process information enters the Performance Assessment level from Level One. The Performance Assessment level calculates actual component efficiencies, capacities, heat rates, etc., and compares these values to values obtained from the performance models. Instantaneous incremental costs of power or steam production from each source are calculated, and any deviation between actual and predicted performance is expressed in terms of cost of additional fuel, and/or power resulting from performance deterioration. The results of the Performance Assessment calculations are forwarded for use by Level Three - Human Interface, and Level 5 - Plant Optimization.

LEVEL THREE - HUMAN INTERFACE

The Human Interface level is responsible for presenting all pertinent information on the cogeneration system to plant operators, maintenance technicians, performance engineers, and management personnel, as well as serving as a means of issuing operator commands to the Base Regulatory and Sequential Controls. As depicted in Figure 2, the Human Interface level receives information from Levels One and Two, monitors commands from Levels Four and Five (which it can override), and issues commands to Level One.

Functions performed at the Human Interface level include the following:

- Manual Control from Process Graphic or Station Displays
- On-Line Monitoring
  - Process Graphic Format
  - Tabular or Text Format
- Alarm Management
  - Alarm Prioritization
  - Alarm Annunciation
  - Alarm Acknowledgment
  - Alarm Logging
- Trending
  - Component and Plant Performance Trends
  - Process Variable Trends
- Report/Log Generation
  - Shift Reports
  - Operator Action Logging
  - Monthly Reports
  - Performance Assessment Reports
  - Operating Cost Summaries
  - Trip Logging
- Data Storage
  - Short Term
  - Long Term

LEVEL FOUR - SUPERVISORY CONTROLS

The Supervisory Control level automates operator functions and performs advanced control algorithms involving one or more of the Level One Operational Segments. Unlike Base Regulatory and Sequential Controls, Supervisory Controls are not absolutely required to operate a cogeneration plant, but rather serve to operate it more efficiently, safely, and in a manner designed to extend equipment life. The Supervisory Control level receives the bulk of its information from Level One and issues directives to Level One, usually in the form of setpoints or on/off commands; these directives may be overidden at the Human Interface level.

Typical Supervisory Control functions include the following:

- o Automatic Start-Up Sequencing of Cogeneration Plant
  - Gas Turbine Start-Up and Loading

- o Automatic Shutdown Sequencing of Cogeneration Plant
  - HRSG
  - Steam Turbine
  - Gas Turbine

- o Load Shedding
  - Electrical
  - Steam

- o Steam Header Pressure Control
  - Coordinated Operation of Extraction Valves, Pressure Reducing Valves, and Vent Valves
  - Feedforward from Process Steam Users for Anticipatory Action
  - Rotor Stress Calculations for Steam Turbines

- o Tie - Line Demand Control
  - Fixed Demand Window
  - Sliding Demand Window

LEVEL FIVE - PLANT OPTIMIZATION

Plant Optimization is the highest level of the Strategic Cogeneration Management System. The Plant Optimization level uses linear and mixed integer programming techniques to optimize facility-wide energy production and supply.

Once the cogeneration plant reaches a relatively steady-state condition (constant overall load), the Plant Optimization program is enabled. The Plant Optimization program calculates the most economical operating mode for the energy system as the solution to the minimization of a energy cost objective function. Coefficients for the energy cost objective function are derived periodically on-line from cost data obtained from the Performance Assessment level. The coefficients are load dependent and change over time due to equipment performance degradation (e.g., fouling, wear, etc.). Equipment capacities, operational limitations, and steam and electric user requirements are modeled by constraint functions incorporated into the linear and mixed integer programs.

The output of the Plant Optimization level are instructions sent to the Supervisory Controls primarily in the form of load setpoints and major equipment start-up/shutdown commands.

HARDWARE IMPLEMENTATION

Implementation of the five hierarchical levels described herein can be accomplished most cost effectively in a strategic process management system. Figure 3 shows the physical arrangement of a typical strategic process management system for cogeneration. Process Control Units (PCUs) housing Multi-Function Processors and their associated input/output slave modules are distributed throughout the facility. Distribution of the PCUs near each major piece of equipment minimizes the length of cable runs (and thus installed cost) while also providing functional partitioning for increased system integrity. The computing power of the Multi-Function Processors and the ability to communicate between PCUs via a 10-megabaud data highway permits implementation of Base Regulatory and Sequential Process Controls, Performance Assessment, and Supervisory Control all at the PCU level. The resulting advantages include more timely information, reduced complexity, and reduced spare parts requirements.

The Human Interface level physically consists of an integrated operator console located in a central control room. Separate Operator CRT-Keyboard Interface Stations are assigned to the Steam Turbine, Gas Turbine, HRSG and BOP, Plant Control, and Alarming during normal operation. However, each Operator Interface Station is capable of displaying all system screens to facilitate major equipment start-ups and to provide redundancy in the event of an Operator Interface Station failure. Printers are provided for alarms and reports, with both printers having the ability to generate hard copies of screen displays upon operator request. Floppy disk, magnetic tape, or optical disk drive units are provided for long term data storage.

The Plant Optimization level is implemented in an external computer which communicates to the PCUs via a standard serial link. An external computer is utilized for the optimization function because of the necessity to manipulate large matrices in solving for the minimum solution to the energy cost objective funtion.

CONCLUSION

The use of a Strategic Process Management System for cogeneration as described in this paper helps ensure that the maximum possible return on investment is achieved from the cogeneration plant. The Strategic Cogeneration Management System maximizes return on investment by:

- Operating the cogeneration plant so as to minimize the cost of steam and electricity production while meeting the needs of steam and electric users;
- Reducing the frequency and severity of unplanned downtime by identifying degradation in equipment performance before failures occur.

REFERENCES

[1] Curtin, D., and Hinson, F., "Advanced Cogeneration Control, Optimization, and Management: A Case Study", Bailey Controls Company Technical Paper, 1988.

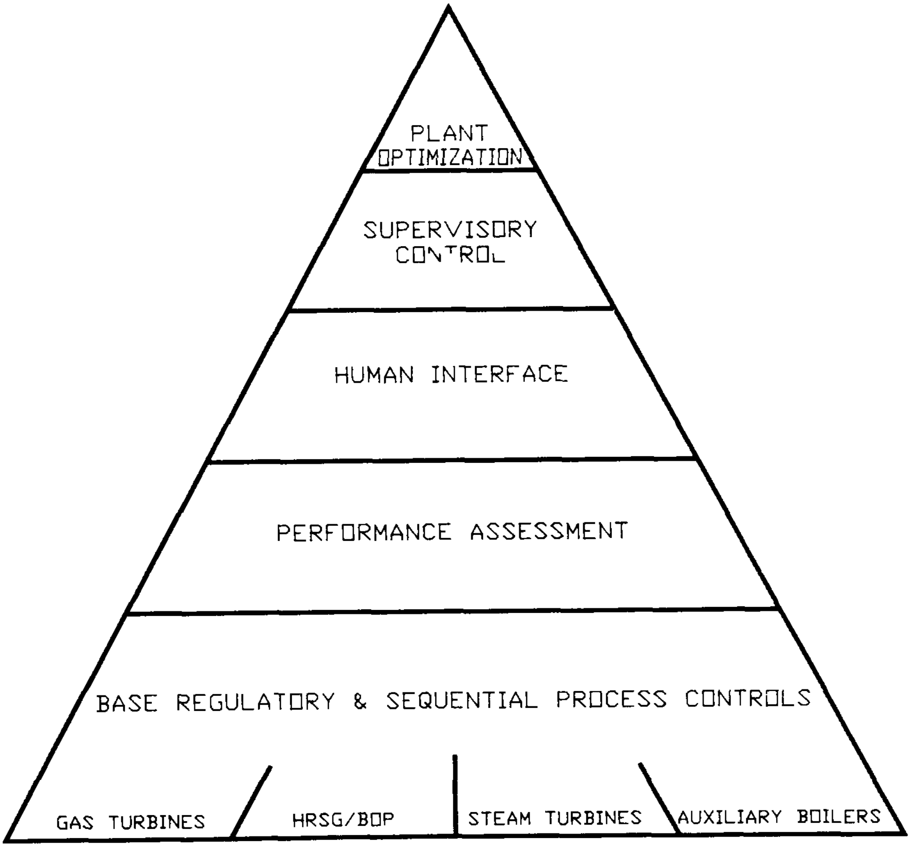

FIGURE 1 Strategic Cogeneration Management System Hierarchy

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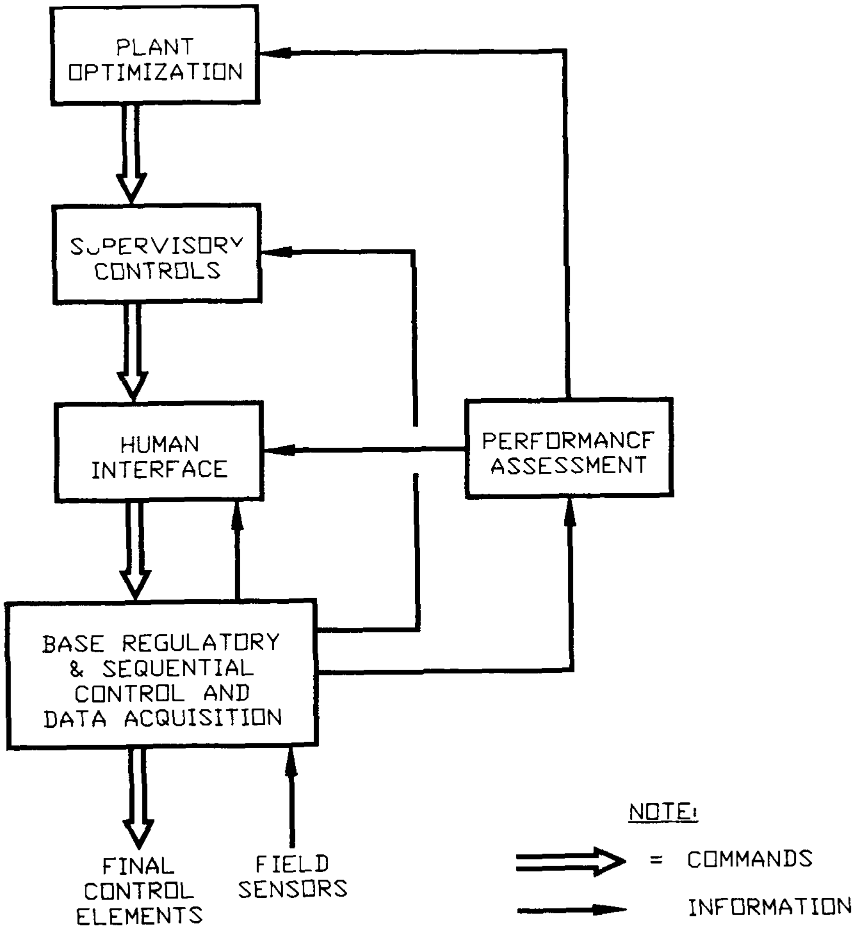

FIGURE 2 Flow of Information and Commands

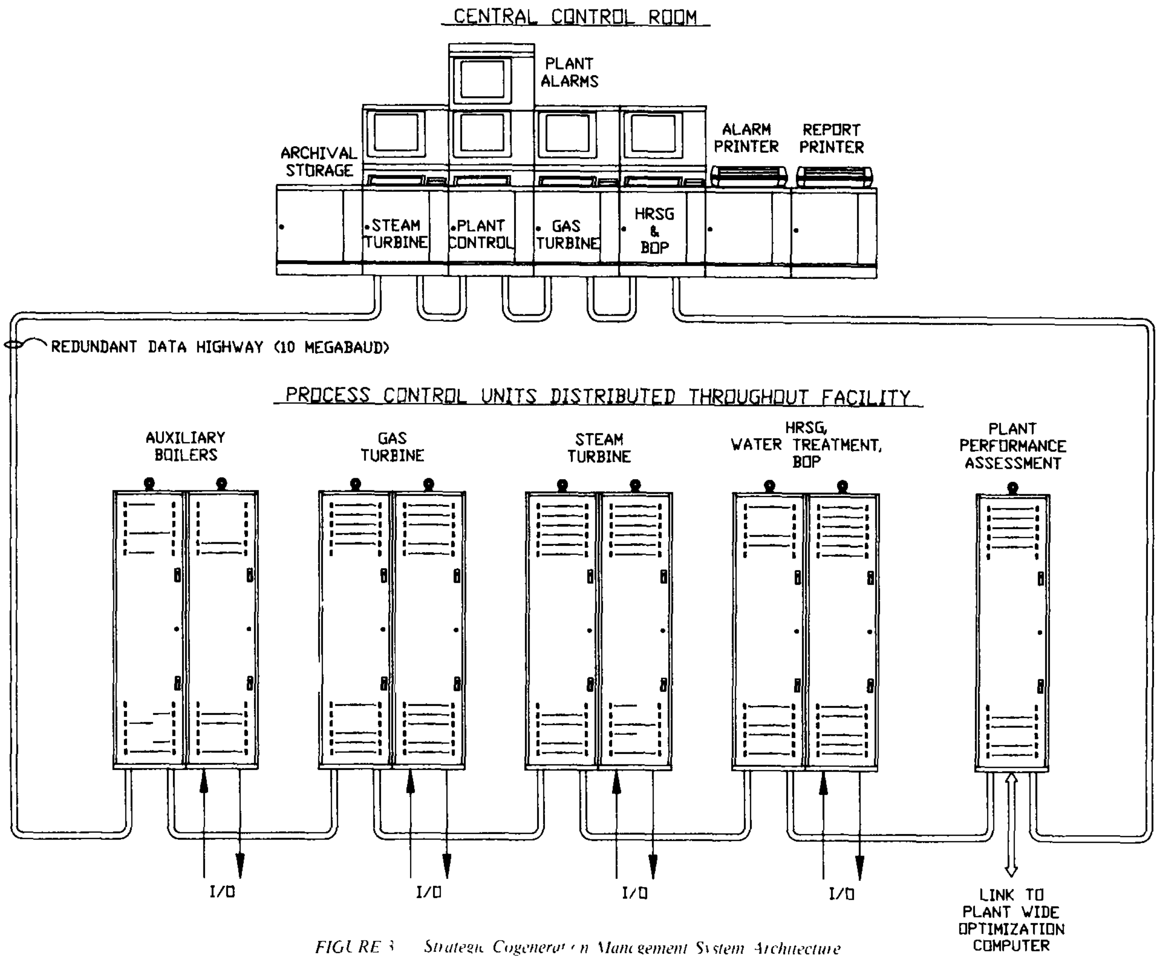

FIGURE 3 Strategic Cogeneration Management System Architecture

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