ISSUES OF INTEGRATING HIGH-TECH CONCEPTS INTO NUCLEAR POWER PLANT OPERATION

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THE FUNCTION AND DESIGN OF NUCLEAR POWER PLANT CONTROL ROOMS IS EVOLVING Owing TO THE FLOOD OF HIGH-TECH SYSTEMS

- Monitoring, Diagnostics, and Control
- Many Organizations Are Developing New Plant Monitoring and Control Systems
- Choice of Many Alternative Designs and Configurations ... No Universal Technology or System Organization
- Obsolescence
- Availability
INCREASED FLOW OF DATA TO OPERATOR — RAW, LIVE, STORED — CAN CAUSE CONFUSION AND OVERLOAD

- Live Sensory Data
- Recalled Data from Data Bases
- Suggested by Expert Systems
- Generated by New Control, Diagnostic, and Monitoring Software
- Displayed in Many Forms ... VDU
SURVEY OF CURRENT AREAS OF DEVELOPMENT SHOWS A BROAD SPECTRUM OF ACTIVITIES

- Real Time

  Sensor Validation
  Sensor Redundancy Techniques
  Data Transmission
  Alarm Systems and Diagnostics
  Prognostics
  Operator Interface Displays
  Plant Performance Optimization
  Control Algorithms
  Computer Fault Tolerance
SURVEY OF CURRENT AREAS OF DEVELOPMENT SHOWS A BROAD SPECTRUM OF ACTIVITIES (Continued)

- Non Real-Time

  Storage and Recall of Procedures
  Monitoring of Plant Technical Specifications
  Predictive Maintenance
  Maintenance History of Components and Systems
  Fuel Loading Data Bases
  Valve, Breaker, and Motor Tagging Logs
  Maintenance Work Requests
  Bypass Logs
LAYERS OF HIERARCHY
IN AN INTELLIGENT CONTROLLER

SLOW RESPONSE
(NON REAL-TIME SOFTWARE)

CONFIGURATION

STRUCTURE

ADAPTATION

PARAMETERS

OPTIMIZATION

SET POINTS

REGULATION

CONTROL

MEASUREMENTS

PROCESS

FAST RESPONSE
(REAL-TIME SOFTWARE)

STRUCTURAL CHANGES FOR MANEUVERS AND COPING WITH DEGRADED EQUIPMENT

ADAPTING TO LONG-TERM VARIATION OF PLANT PARAMETERS AND OTHER NONLINEARITIES

MINIMIZATION OF ERRORS AND CONTROL ACTIONS

SERVO CONTROL OF THE PROCESS
THE EFFECTIVENESS OF CONTROL ROOM SYSTEMS CAN BE ASSESSED BY APPLYING MEASURES OF UTILITY

- Sometimes Designers Fixate on a Particular Attribute of a Technology

- Engineering Judgement Still Required

- Measure System's Effectiveness Against Criteria... Some Hard, Some Soft

- Criteria Suited to Type of System Under Evaluation

- Measures of Utility Consist of Criteria, Tests, Questions, Benchmarks

- Measures of Utility Identify Distinctions Between System Properties to Allow Informed Judgement
MEASURES OF UTILITY CAN BE CREATED FOR MAJOR SYSTEMS CATEGORIES

- **Interface**
  - Control Panels
  - Displays
  - Human Input Devices

- **Monitoring and Diagnostics**
  - Status Monitoring Software
  - Sensor Validation

- **Control (Components and Algorithms)**
  - Continuous Processes
  - Discrete-Event Processes

- **Procedural**
  - Procedure Recall
  - Predictive Maintenance
  - Maintenance Tracking
  - Fuel Loading Calculations
A FIRST ATTEMPT AT MEASURES OF UTILITY FOR INTERFACE SYSTEMS

Measures of Utility Checklist for Interface Systems

1. Compatibility with Human Operators
   Meaningfulness of Information
   Understandability
   Legibility
   Attributes of the Display
   Data Entry

2. Real-Time Quantitative Performance
   Feedback
   Response Time
   Update Time

3. Reliability and Availability of Results or Conclusions

4. Resource Requirements
   Environment

5. Future Considerations
   Flexibility
   Maintainability
NUMEROUS CONTINUOUS CONTROL TECHNIQUES MAY BE APPLIED TO POWER PLANT SYSTEMS

- PID (Classical SISO Feedback Control)
- Feedforward Control Schemes
- Adaptive Control (Self-Tuning)
- Hierarchical Control (Multiple Layers Of Control)
- LQG
  - With or Without Estimation
  - Robust Synthesis
  - Multiple Linearizations
- Closed-Loop Nonlinear Control (Unknown System Dynamics)
- Fuzzy-Logic Control (Rule-Based ... Nonlinear Gains)
- Reconstructive Control (Inverse Dynamics)
- Neural Networks
THERE ARE DIFFERENCES IN DESIGN AND OPERATION OF COMPETING CONTROLLER TECHNOLOGIES

- Algorithm
  - Mathematical Methodology
  - Process Strategy
- Model Usage
- Measurement Sets (Input Variables)
- Control Regimes (SS, Start-up, Transients)
- Stability Characteristics
- Robustness Characteristics
- Required Tuning Methods
- Resultant System's Dynamic Response
- Method of Presetting Process Setpoints
- Demands on Computing Resources
Field Personnel

Objective

Overshoot Damping Ratio

Tuning Method

$K_p, K_i, K_d$

Tuning Parameters

Controller Gains

Controller

Plant
Objective

Robustness Planning

Response Tailoring

Solve for Optimal Control Gains

Controller Gains

Controller

Plant

Computer Calculations

Margins

Tuning Parameters

Singular - Value Plots
- Return Ratio
- Return Difference
- Inverse Return Difference

Weighting Matrices

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A FIRST ATTEMPT AT MEASURES OF UTILITY FOR CONTROL SYSTEMS

Measures of Utility Checklist for Control Systems

1. Compatibility with Human Operators
   Meaningfulness of Information
   Understandability

2. Real-Time Quantitative Performance
   Dynamic Performance
   Frequency-Domain Characteristics
   Accuracy and Precision of Results

3. Reliability of Results or Conclusions

4. Tolerance to Degraded Conditions
   Robustness to Modeling Errors
   Robustness to Noise Corruption
   Process Parameter Variation
   Sensor and Actuator Failure
Measures of Utility Checklist for Control Systems
(Continued)

5. Effects on Nearby Components and Subsystems
   Actuators
   Subsystems

6. Ability to Tune in the Field

7. Resource Requirements
   Real-Time Computational Requirements
   Sensor Count
   Measurement Accuracy Requirements

8. Future Considerations
   Flexibility
   Maintainability
A FRAMEWORK FOR EVALUATING OPERATIONAL ATTRIBUTES CAN FORM A UNIFORM BASIS FOR CONTROL SYSTEM TEST AND ACCEPTANCE

- Identify Which Measures Of Utility Apply To Specific System Under Design

- Weight The Importance Of Each Utility

- Rate The Alternative Control System Designs Using The Weighted Measures Of Utility

- Use The Outcome Of This Analysis To Shape The Final System Selection and Design
THE MEASURES-OF-UTILITY CONCEPT PROVIDES AN INITIAL FRAMEWORK FOR COMPARING PLANT SYSTEM PROPERTIES

- Interface and Control Systems
- Integration and Coordination of Control Room Systems, Equipment, and Software
- Design Is Always a Compromise
- Need to Expand and Refine the Measures of Utility
- Fuzzy Logic Techniques May be Useful in Applying Measures of Utility