ICEX'95 Paper

Benchmarking Controls Performance for Upgrading to DCS

D A Parker BE, BSc
Senior Engineer/ Control and Instrumentation Systems
Pacific Power

ABSTRACT

A Life Extension programme for power plant usually involves replacement in part or whole of the Unit Control System hardware. Upgrading to a modern DCS provides the opportunity for improving the design of the modulating controls. However, new design concepts may require much additional engineering effort, gathering of plant data and testing. The most basic justification for hardware replacement is equipment reliability and availability of spares, and the benefits of changing design concepts are often difficult to establish.

Benchmarking control system performance prior to replacement can provide essential information for decisions on controls design upgrading. In this paper, a benchmarking procedure is outlined which has been used by Pacific Power to assist in separating plant performance problems from control system design deficiencies and making quantitative judgements about the actual and required performance. It describes the establishment of performance criteria, open and closed loop response testing and modelling of control options. The procedure helps establish the areas where re-design of controls or use of advanced controls are required to meet plant and operational requirements.

INTRODUCTION

Upgrading to a modern DCS provides the opportunity for improving controls designs and making substantial improvements to plant dynamic performance.

While this may be considered generally desirable, implementing new (particularly "advanced") design concepts requires additional engineering effort, data collection, testing time, and possibly retraining. How much of the old design philosophy do you keep? How do you judge where to concentrate the engineering effort to maximise the economic benefit? Control system performance often deteriorates over time for various reasons, and it is difficult to assess whether re-design of the controls will solve all the problems. Over the station's lifetime, poor loop performance can be brought on by such factors as:

a) **Plant/sensor modifications**

For example: Transmitter range changed, process filter applied, a faster actuator installed, valve fitted with a new characteristic.

3.4 PA Bus Pressure Control

In power plant where Primary Air Bus pressure is controlled by PA Fan output, a fast response loop is essential to maintain tight control over fuel flow. Bus pressure signals may be noisy and have some resonance components.

Steady state:
Bus pressure to remain within ± 0.2 kPa of setpoint.

Dynamic response:
Load changes up to the maximum rate and during Fan sequence starts - to remain within ± 0.4 kPa of setpoint, settling within 15s from the end of the disturbance. Fan balancing to be achieved within 1 minute during a start.

Boiler unloadings:
Due to PA Fan loss - Unit to remain in service (ie Bus pressure to be kept above the trip point).
Due to other than PA Fan loss - within ± 0.8 kPa of setpoint.

Signal noise:
Less than 0.2kPa p-p.

3.5 Fuel Flow Control

Accurate control of total fuel is essential for safe combustion and for optimisation of Boiler pressure and temperature controls. Response should be directly with Fuel demand, with no overshoot or undershoot. Inherent lags in fuel output should be compensated for dynamically wherever possible.

Steady state:
Total Fuel Flow to remain within 1% CMR of Fuel Demand.

Dynamic response:
Total Fuel Flow to remain within 3% CMR of Fuel demand signal under all normal load changes up to the maximum rate, and during Mill starts or shutdowns. Fuel/Air cross limits not to be activated during normal load changes. Mill balancing to be achieved within 2 minutes of being brought into service.

Mill Trips:
On Mill trips, (and Feeder trips for table mills) Total Fuel Flow to return to within 5% of Fuel demand signal in 30 secs, unless limited by Mill dynamic response.

Boiler unloadings:
Total Fuel Flow to remain within 5% CMR of Fuel demand signal. Transient activation of Fuel/Air Cross limits is acceptable, however Fuel-Air alarms should not be initiated.

Signal noise:
Less than 2% CMR p-p. Signal filtering ≤ 2 secs.

Sample from Pacific Power's

b) Plant problems

For example: Worn linkages and valve seats, sticking bearings, blocked sensing lines, sloppy actuator feedback gearing.

c) Controls problems

For example: Failure of a "hidden" component of analogue control hardware such as a feedforward signal or integrator capacitor, which may not force the loop to Manual, but cause much degraded performance.

Many of these show up as plant instability, and a controls "solution" of detuning is often employed – in good faith as an interim measure. Thus, gains are lowered, integral times lengthened, feedforwards reduced, filters added and deadbands are increased until the problem is solved. Since the urgency for the total solution has been reduced, it may be that the controllers are left in that state. The real problem behind unsatisfactory performance may therefore be a combination of plant/controls hardware faults and poor controller settings.

Power plant has also needed to become more flexible, shifting load more often and at higher rates of change. However, many older systems were simply not capable of controlling some of the plant parameters for anything other than "base load" operation. In these cases, a revised or advanced design may be necessary to achieve the required flexibility and performance from the new system.

SYSTEMATIC BENCHMARKING

Testing current control system performance can provide essential information for decisions on both plant and controls design upgrading. However, procedures are required to ensure the actual causes of poor response are found.

The benchmarking procedure involves:

- Setting desired performance standards
- Open loop response testing
- Closed loop testing and optimisation
- Making quantitative judgements on performance

SETTING PERFORMANCE STANDARDS

A performance standard is established that sets out

i) the acceptable limits of process variable errors, allowable process noise, filtering, damping, etc for each control loop. These limits relate to steady state, normal dynamic situations and major plant disturbances, and

ii) the test conditions (load ranges, ramp rates, etc) that apply to each limit in the standard.

The limits are set to strictly meet plant and operational requirements. Poor control of a loop may effect the plant in a number of ways, such as:

- inability to handle disturbances, leading to load reductions or unit trips, – loss of plant efficiency,
- reduction in loading rate,
- early plant failure from effects including thermal stress, erosion, corrosion and failure of controlling elements.

The control design engineer must understand these effects, and from them set both process limits and desired shape of response. The review should answer such questions as:

- is the aim to minimise overshoot, time to settle or absolute integrated error? – can any long term offset be tolerated?
- is there any limit to the rate of change of PV? – what is the interaction with other loops? – how active is the actuator to be ?
- what signal filtering can be tolerated? (signal lag becomes part of the process dynamics.)

OPEN LOOP TESTS

These tests perform two functions:

i) Plant/measurement problem identification.

Plant and measurement problems can be masked by closed loop control action. Often the steady load operation may be satisfactory but load changes become more difficult. It can be hard to pinpoint the problem whilst on Auto.

With simple but carefully performed open loop tests over the plant's working range, many problems with the plant and process can be identified. This enables control system performance problems to be separated from design deficiencies.

Problems often found with these checks include linkage hysteresis, positioner inaccuracy, nonrepeatability of performance of plant, process noise and sensing delays such as line blockages or sample transport times.

This approach has been taken to the analysis of various problems on a number of stations in NSW.

Examples of problems found:

a) FD Fan blade hysteresis.

The Forced Draft Fans supply the majority of air to the furnace. Blade pitch is adjusted to match total air flow to fuel demand, with flue gas oxygen as a trim. Hysteresis could be confirmed by comparing air flow or excess oxygen with vane position. In Fig 1, the FD blade actuator or linkage hysteresis is seen in the oxygen response.

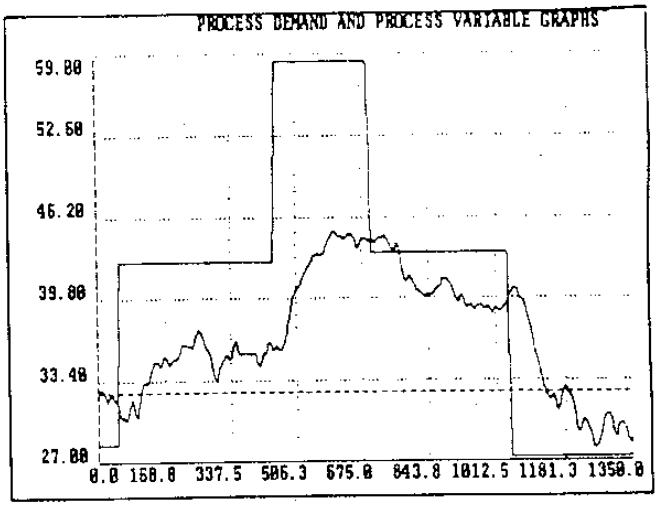

Figure 1

b) Highly varying gain over the load range.

Open loop tests can quantify the process gain and time constants vs load, for gain scheduling or position feedback characterisation. Open loop tests on a SFP at one station helped to identify the source a severe stability problem in the feedwater controls (Fig 2). It was shown that loop gain varied greatly over a small control range, and the feedwater could change without any indicated actuator position change. This appeared to be a problem in the throttle valve controller.

SFPs at another station had similar problems, made worse by the steam supply and exhaust arrangement. Open loop tests prompted research into a non-linear model and the option of using advanced control in the planned DCS replacement.

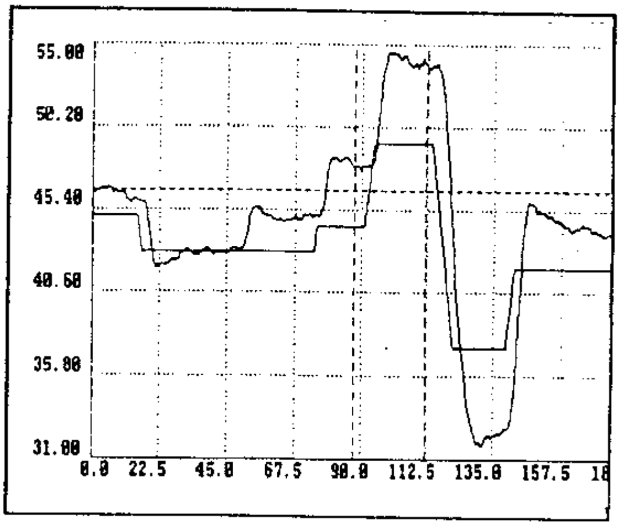

Figure 2

c) Sensing line blockages.

An instance was found where several partially blocked mill air flow transmitter sensing lines had caused instability in the fuel control loop, resulting in a slow oscillation of boiler pressure, fuel, steam temperature and MW. The process appeared to be very difficult to control. However, an open loop test showed why instability had resulted: the partial blockage in one leg was producing a transient positive feedback in the mill control loop each time fuel demand changed.

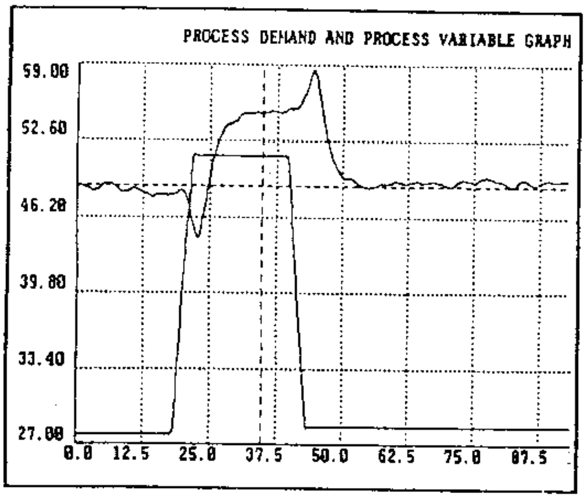

Figure 3

ii) Process characteristic identification.

Characteristics of each process is determined to help deduce the suitability of the current design. Open loop checks can identify interactions between process variables and response variations with load. They will also help identify the order of the system and provide values for system dead time, time constants, and process gain as a function of unit load, steam pressure, etc.

This information can also be used to set up the new control system tuning parameters.

CLOSED LOOP TESTING AND OPTIMISATION

It may seem pointless tuning a control system shortly before it is to be replaced. Yet closed loop tuning is required to ensure the system as currently designed is operating at its optimum, to get meaningful benchmarking results. Tuning is worked through systematically from low level non-interacting loops to high-level Coordinated systems. Final performance should be best in the mid to high load region whilst keeping a good stability margin at low load.

Tuning can be conducted by the experimental approach of adjustment and observation. However the use of open loop test results and established tuning calculations give a close result much more quickly. On-line loop analysis tools may save much time in this phase.

Once tuning is satisfactory, the performance standard is used to establish the tests to be conducted and acceptance criteria for process responses. Fig 4 shows a typical testing programme for Power Plant.

A summary table of standard and measured responses is produced to assess performance.

MAKING QUANTITATIVE JUDGEMENTS ON PERFORMANCE

Comparisons between standard and actual performance across the load range highlights those loops where controls design upgrading should be considered. Increasing the sophistication of the controls concepts may indeed produce significant improvements, where performance does not meet the standard. However, it may equally be found that, even for very complex plant the performance is already satisfactory. Hence only the design work that may add value is pursued.

MODELLING AND UPGRADING CONTROLS DESIGN

Figure 5 summarises the benchmarking and review procedure. Where the performance did not meet the criteria set in the standard, plant and controls may need to be modelled to quantify the benefits of upgrading the design.

Open and closed loop response results provide basic plant data for developing plant and control system models. For complex systems, physical models can be

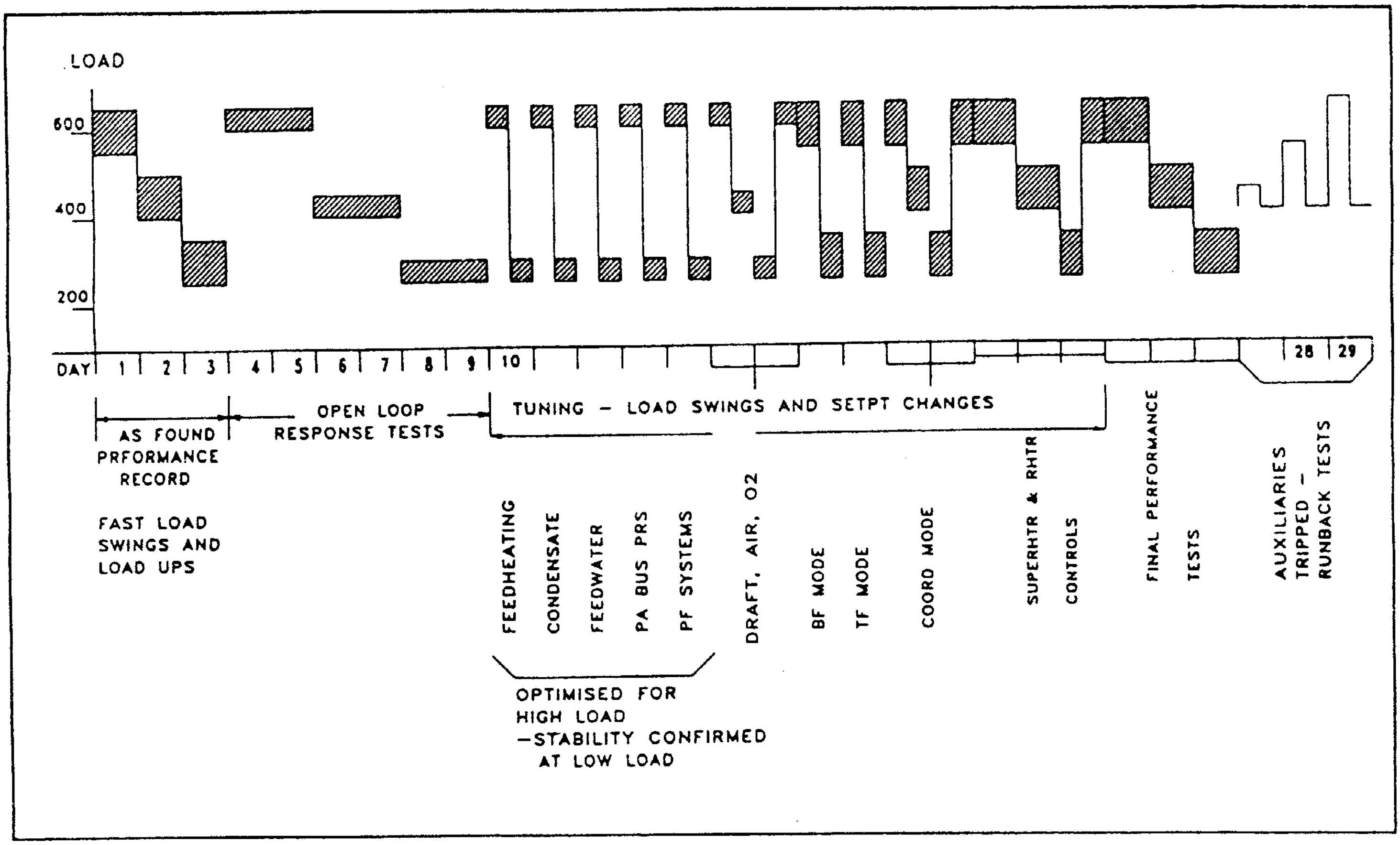

Figure 4
Typical Benchmarking programme for power plant.

developed and compared with actual performance. Control loop analysis and modelling software packages can greatly assist this process. Control options can then be added to the model. These may include simply more sophisticated classical designs such as cascade control, gain scheduling and feedforwards, or advanced solutions including model-based control and adaptive techniques. The level of sophistication should reflect the loop's controllability and performance requirements. It should be noted that an over-simple model may give inaccurate, but very impressive, control responses particularly if the controller has been based on the same model!

In power plant, advanced control techniques have been usually only worth considering on a small number of loops. These typically include steam temperature and pressure control – high order, multiple input/multiple output systems with fairly stringent dynamic performance criteria. However, the areas of application are increasing as power plant is required to operate with greater flexibility, and as plant failure mechanisms become better understood. Recent contenders for control concept improvements include gas air heaters (heat transfer performance optimisation and improved cold-end temperature control), feedheater level control in Nuendorfer [1], deaerator transient control for feed pump protection in Marshall and Peattie [2] (a Pacific Power investigation), and PF mill control in Rees and Fan [3]. New limitations must be added to the Performance Standard to ensure the benchmarking process remains accurate.

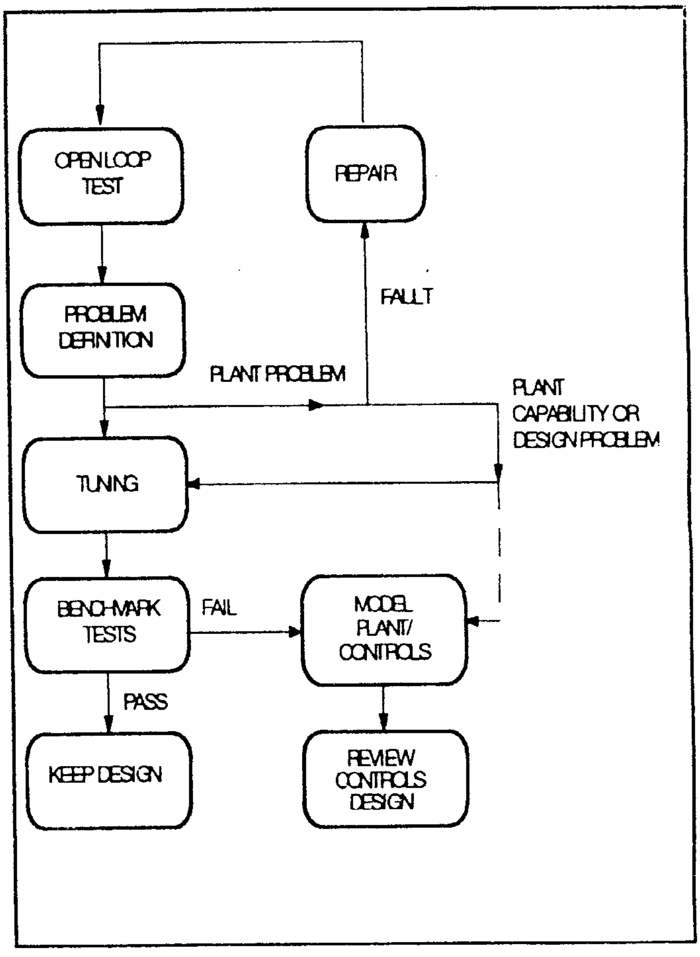

Figure 5
Benchmarking / Review procedure

OTHER BENEFITS FROM BENCHMARKING

If the benchmarking tests are repeated after the DCS is commissioned and adjusted, a comparison can be made of the before and after replacement performance of the unit control system. This may be used as one of several indicators of the project's success.

The results also provide base data for ongoing maintenance. If the procedure is repeated after several years, many plant and control problems can be readily identified and performance brought back to standard.

CONCLUSION

Benchmarking controls performance prior to replacing with a DCS can provide important insights into the ability of the old design to meet the plant's dynamic requirements. By using a procedure which first identifies plant problems and establishes a performance standard, a set of tests can be conducted that highlight where the existing design is inadequate.

This enables the controls design for the new DCS to be upgraded in the areas of greatest benefit. The data gathered during the benchmarking exercise can also be used to develop models for testing the control options being considered.

Benchmarking may also be used to assess improvements to control after the DCS is installed, and as a maintenance procedure.

REFERENCES

1. Nuendorfer m. and Frerichs D.K. "Advanced Feedwater Heater Control" 57th American Power Conference, April 1995
2. Marshall J.E. and Peattie W.S, "A Link between Plant Transients and Boiler Feed Pump Failures" 57th American Power Conference, April 1995
3. Rees N W and Fan G Q. "Control of Vertical Spindle Mills in Coal Fired Power Plant", ICPST '94, Beijing, PRC.