THE 'SYSTEMS APPROACH' TO INDUSTRIAL CONTROL SYSTEMS DESIGN, DEVELOPMENT AND IMPLEMENTATION USING IEC 61131

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The Control Systems Development Lifecycle Using a 'Systems Approach'

1. Process Model Development
2. Control Systems Design
3. Modelling and Simulation
4. Control Systems Implementation
5. Testing and Commissioning

1 Process Model Development

There are three main types of approach for developing computer models to represent real processes and systems :

i) Derive models from first principles – text book approach
ii) Assume linear approximations for non-linear systems – simplified representations of complex systems [1]
iii) Derive models from real site data using 'System Identification' techniques [2]

In general, no matter what level of detail and complexity a model may go into, at the end of the day it will still only be a simple reflection of reality [3]. What is more important to bear in mind is that the system model in our case is being developed specifically for **control system design purposes.** As such, the requirements of the model will be very different from if it was being developed for say mechanical design engineering purposes.

When developing process models for control system design purposes, the key is to be able to gauge what level of detail is required in order to capture the most important features and characteristics of a process. It is often necessary to reach a compromise between complexity and simplicity. Too much model detail can result in excessive development times, slow processing / simulation times and possible calculation instability problems. Too little detail and important process characteristics and behaviour may be overlooked. Knowing where to draw the line in terms of model complexity is crucial if these techniques are to be applied successfully. However, such skills are normally acquired only through experience.

In summary, a good model for control systems design purposes will allow the meaningful testing and evaluation of the various different types of control systems available without going into excessive detail when attempting to represent the process.

Because of the power and flexibility offered by the IEC 61131 standard, process models developed using any of the above techniques can be coded and tested easily and efficiently prior to the phase of applying the closed-loop control algorithms designed to regulate the process.

2 Control Systems Design

Develop a library of industry standard controller type function blocks in IEC 61131.

e.g. PID controllers, fuzzy logic, genetic algorithms, H Infinity, LQR, filters, relays, rate limiters, saturation blocks, limited integrators, quantization blocks etc.

All function blocks should be fully tested prior to their inclusion in the software library in order to guarantee their performance when used in real applications. Such methods promote the development of modular re-useable code with the net result of increased software productivity and coding efficiency.

3 Modelling and Simulation

Undertake closed-loop process control simulations in IEC 61131.

Test and evaluate the different types of controllers available and select the most appropriate type of control system for the process.

A well-designed, robust industrial control system should be able to compensate and react to real plant non-linearities and disturbances. In a similar way, it should be possible to demonstrate these important control system features in a model simulation environment.

(A major benefit of adopting this type of controls systems development methodology is that simulations can be run many times faster than real time, so these techniques are equally well suited for industrial processes with long process time constants. e.g. power stations, oil refineries, chemicals plants, water and waste water treatment works, tidal pumping stations, sea barrage defences etc.)

4 Control Systems Implementation

Implement the selected control system using IEC 61131. This stage of the design methodology involves removing the process model components from the developed IEC 61131 simulation and interfacing the remaining control algorithms to the real plant.

i.e. Direct transfer from simulation code to PLC using IEC 61131 (no control algorithm re-coding required) – minimisation of coding errors.

5 Testing and Commissioning

On-site testing, loop tuning and optimisation.

The key benefits of undertaking the modelling and simulation work in IEC 61131 prior to this stage of the control system development lifecycle will become evident during the final testing and commissioning of the plant.

Benefits include:

improved software testing methods
reduced commissioning times
optimised process control
greater understanding of complex processes

An additional benefit of the modelling and simulation work is that any simulations developed can also be used as a training tool for systems engineers and plant operators.

6 Case Study

Didcot Power Station

Steam Return and Feed Water Make-up Cycle – Loop Tuning and Optimisation [4].

Didcot Power Station Model Simulation Using IEC 61131

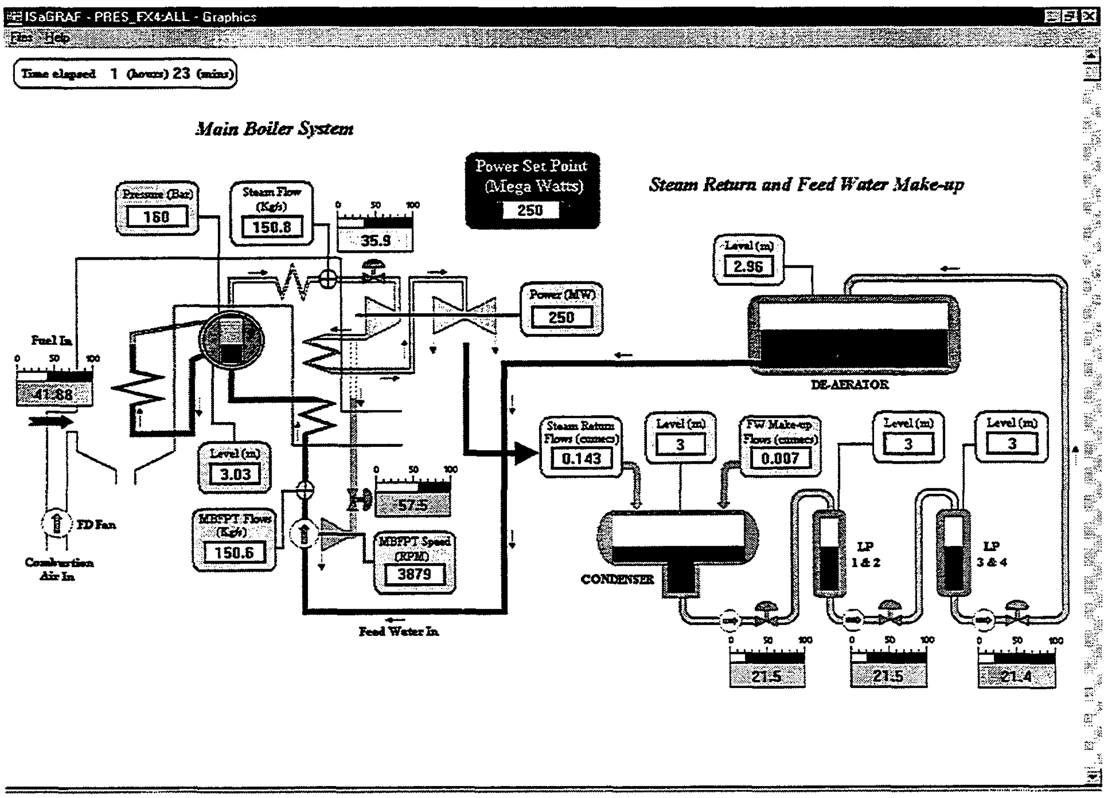

Figure 1

6.1 Problem

Level stability issues in the condenser and LP heater vessels for a given flow change in the closed-circuit water/steam/water process cycle as a result of a variation in unit power output.

6.2 Method of Analysis

A representative model of the overall system was developed in IEC 61131 using a combination of deriving the model from first principles (text book approach) and linear approximations for non-linear systems (simplified representations of complex systems). The three on-site PID control algorithms used to control the condenser and LP heater levels were then added to the model (including the problematic tuning parameters). A number of simulations aimed at assisting in the overall understanding of the process and its system dynamics were then undertaken. The ultimate objective of this whole exercise being to stabilise and improve the performance of the three on-site PID control loops so as to provide robust control over the full operating range of the plant.

6.3 Results

The PID algorithm [5] employed in the simulations was of the type:

$$Actuator\_Output(\%) = \frac{10000}{Span * PB}\left(Error + \frac{1}{TI}\int Error\_dt + TD\frac{dError}{dt} \right)$$

where Span is the range over which the process is intended to operate (metre units in this case)
(Span = Span High – Span Low)
PB is the proportional band tuning parameter as a percentage of the span
TI is the integral time tuning parameter in seconds
TD is the derivative time tuning parameter in seconds (not used in these simulations)
Error = Process Value (PV) – Set Point (SP)

If **'proportional action only'** is required then TI should be set to zero in the PID controller.

6.3.1 Model Simulation Results Using the Existing Problematic Site Control Parameters

Figure 3 shows the untuned system response for a 250MW to 300MW power demand step change. The graph clearly illustrates the instability problems of the system, resulting in a desired steady-state equilibrium matching of flows being reached only after a period of approximately 40 minutes. The instability problems are introduced into the system as a direct result of employing PI level controllers as opposed to 'proportional only' controllers which are far more appropriate for flow matching problems such as this [6].

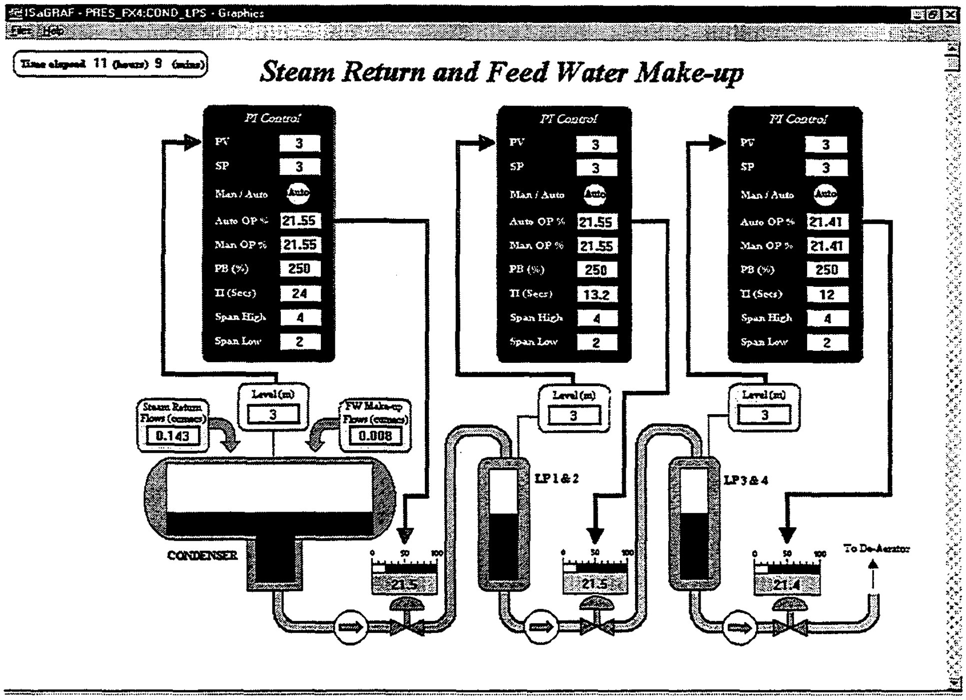

Figure 2: PID controller tuning parameter settings (untuned)

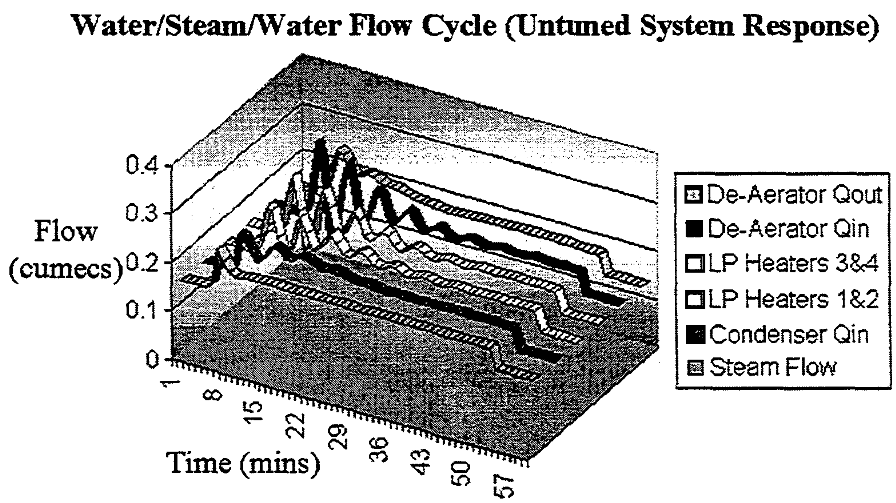

Figure 3: Untuned system response for a 250MW to 300MW step change in power demand

6.3.2 Model Simulation Results Using Optimised Site Control Parameters

Figure 5 shows the optimised system response for a 250MW to 300MW power demand step change. The graph shows the desired steady-state equilibrium matching of flows being reached in less than 20 minutes with minimised levels of oscillation and instability compared to 40 minutes with the untuned system response.

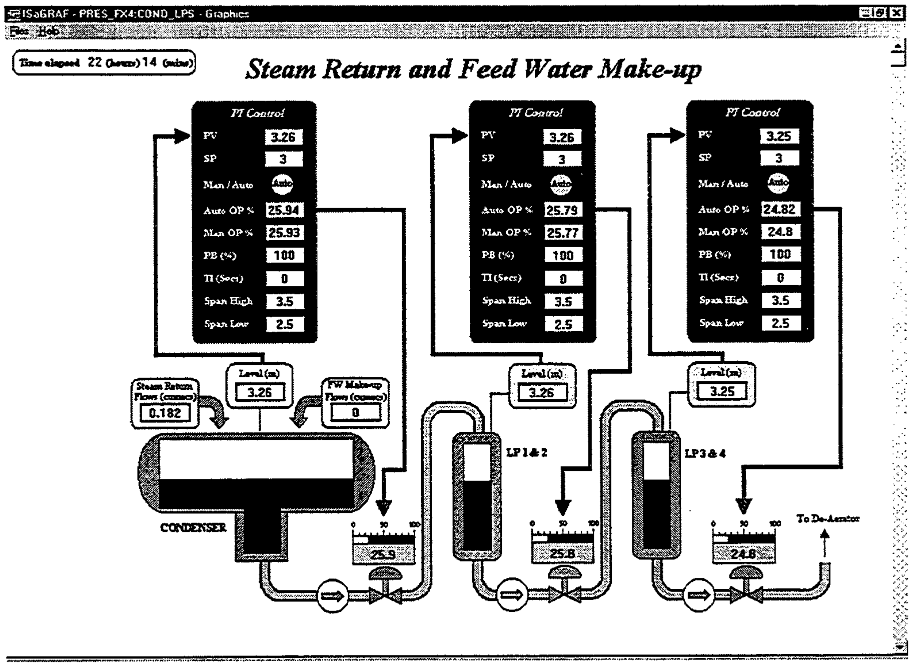

Figure 4: PID controller tuning parameter settings (optimised)

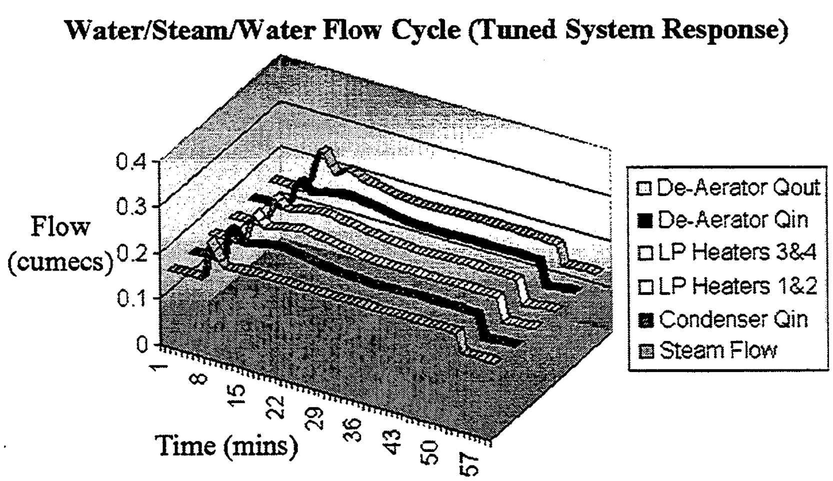

Figure 5: Tuned system response for a 250MW to 300MW step change in power demand

Employing 'proportional only' controllers (by setting TI to 0 secs) introduces damping into the system making the control significantly more stable during power demand variations and for plant disturbance rejection purposes [7].

6.4 Conclusions

Employing the IEC 61131 standard to the task of industrial control systems design, development and implementation in conjunction with modern control systems modelling and simulationtechniques results in a significant number of benefits which include the ability to develop fully tested modular re-useable code. Taking a modern 'systems approach' enables a much greater understanding of complex processes to be achieved which subsequently results in greatly reduced commissioning times and improved process control. These techniques are particularly powerful for systems with very long time constants and slow process dynamics because of the ability to run simulations many times faster than real time.

Another significant benefit of employing modelling techniques is that the simulations developed can also prove very useful for system engineer and operator training purposes.

References

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