Industrial process control

Introducing energy saving opportunities for business
Preface

Reducing energy use makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change.

The Carbon Trust provides simple, effective advice to help businesses take action to reduce carbon emissions, and the simplest way to do this is to use energy more efficiently.

This technology guide of industrial process control techniques introduces the main energy saving opportunities for businesses and demonstrates how simple actions save energy, cut costs and increase profit margins.
Introduction

Process control keeps processes within specified boundaries and minimises variations. Over the last 25 years, most industrial sites have progressively installed modern process control systems to:

- Help maintain throughput, quality, yield and energy efficiency.
- Ensure safe and profitable operation.

During this period, the technology used in industrial process control systems has evolved rapidly and, as a result, UK industry now uses a wide variety of different technologies, ranging from traditional pneumatic control systems to modern distributed, microprocessor-based control systems.

Although the way a modern industrial process control system looks has changed significantly, the traditional hierarchical structure used in the process control systems since the 1970s still applies today. The measurement and control system is the ‘central nervous system’ of any plant and, like the human nervous system, it operates at different levels that sense change and initiate actions (see Figure 1).

*Figure 1 Process control hierarchy*
At the lower levels, basic closed-loop control systems look after plant operations (see page 6 for an explanation of closed-loop systems). If well engineered and maintained, these low-level control systems work automatically and require only occasional intervention during normal operation. However, these systems are not designed to handle complex situations, such as equipment faults, and must be supervised either by operators or by higher-level systems.

The higher levels of the control-system hierarchy, such as supervisory control and process diagnostics, define the process conditions and ensure that efficient operation is maintained.

Did you know?
Improvements in process control can also improve throughput by between 2% and 5%, and reduce the incidence of quality problems by up to 50%.

A well-designed control system has many benefits as outlined below:

- **Energy savings** – a well-controlled plant is energy efficient; poor control is a major cause of excessive energy consumption.

- **Safety improvement** – control systems maintain safe conditions and have built-in alarms to warn of deviations from the operational plan.

- **Consistent product quality** – well-tuned control systems can greatly reduce variation in product quality to meet customer specifications and reduce waste.

- **Reduced manufacturing costs** – good control systems can also reduce manufacturing costs. They can diagnose faults at an early stage in a process to ensure that product throughput and yield is fully optimised.

- **Better environmental performance** – control systems can provide early warning of loss of containment and excessive emissions.
Technology overview

How a process control system works

Basic closed-loop control

Basic closed-loop control is the main building block of any plant control hierarchy, which typically includes many hundreds of individual control loops.

The task of a control loop is to hold a particular process variable (for example, the speed of a mixer or the temperature of a baking oven) at its desired value, or its set-point. This is either determined by higher levels in the control hierarchy or by the operator. The control loop must implement changes in set-point quickly, smoothly and efficiently without disturbing process operation.

The control loop consists of three main components (see Figure 2 on the right).

Figure 2 The main components of a control loop

- Measurement device
- Process
- Controller
- Regulator
- Set-point or desired value
1. The measurement device

To control a process parameter accurately, the control loop needs to be able to measure its value on a regular basis. This is usually done by a sensor that measures a particular physical property (such as temperature or flow rate) and a transmitter that converts the output of the sensor into a standard control signal. This signal is then sent to the controller, which is usually located in a protective enclosure in a central equipment room.

These signals may be sent to the control room individually or transmitted along with other control signals through a dedicated network, known as a Fieldbus.

2. The controller

The controller compares the measured value with its set-point and, where there is a difference, adjusts the process parameter to return the measured value to its set-point. For example, the controller would measure the actual flow rate of a liquid through a process and compare it with the set flow rate. If there was a difference, it would set in motion appropriate changes, such as adjusting the speed of the pump, until the flow rate returned to the desired rate.

Controllers can be configured in many ways, depending on the characteristics of the control loop, the need for accuracy and the desired speed of response.

The single-loop controller is able to handle most of the control tasks found within the process industries if it is correctly chosen and well tuned. For example, single-loop controllers may be used to control temperature in baking ovens within the food and drink industry. In this case, when a sensor detects a drop in temperature, more fuel would be sent to the burners to bring the temperature up to the required set-point.

The single-loop controller normally monitors one measurement and adjusts one regulator, but it can be used to adjust the set-point of another controller. This is known as a ‘cascade system’. For example, in the petrochemicals industry, one common arrangement is for temperature and steam flow control systems to be linked. In this case, the tray temperature control in a distillation column would ‘cascade’ to the reboiler steam flow controller, so that a rise in tray temperature is always preceded by a rise in steam flow.

3. The regulator

A regulator is used to control the throughput of the process. The most common type of regulator consists of a control valve that adjusts the flow in response to the output from the controller. For example, control valves are used to regulate the flow of water around a heating coil to maintain a chemical process at the required temperature.

Alternatively, a variable speed pump may be used to control the flow of the fluid. This not only reduces the amount of energy wasted by throttling the flow, it also allows more accurate control of the flow and eliminates the problem of sticky valves.

Where the controller is regulating the movement of solid materials, rather than a liquid or gas, for example: moving pulverized coal along a conveyor belt into a boiler system, a variable speed drive may be used as the regulator.
Types of control system

As well as basic control loops, there are also different types of system that may be employed, dependent on the functions and complexity of the control required. The most common types are:

- Sequence controllers.
- Distributed control systems (DCS).
- Supervisory control and data-acquisition (SCADA) systems.

Sequence controllers

On some industrial sites, electronic relays and simple on-off controllers are still used to sequence, for example, valve movements and carry out other mechanical operations involved in process start-up and shut-down.

However, these systems are progressively being replaced by sequence controllers such as programmable logic controllers (PLCs). PLCs have a flexible, modular design so they can be expanded in a low-cost way to cover more aspects of process operation as it is automated. Modern PLCs can incorporate single-loop controllers along with more advanced types of controllers. PLCs may be used to carry out a sequence of actions such as adding a colouring dye to cake dough at preset intervals that corresponds with particular consistencies.

Distributed control systems

DCS are normally used to control large or complex processes. They are modular systems that enable operators to adjust the set-points of many individual controllers from a central control room. DCS also include capabilities to sequence process start up and shut down operations and to apply advanced control techniques. For example, DCS may be used in the chemical industry to control multi-process sites. This will enable handling of significant numbers of measurement devices and control loops within the one control system.

Modern, digital DCS are built around a high-speed network or ‘control bus’ that connects each controller to a central supervisory control unit. This unit monitors the operation of each of the controllers and makes data available to other high-level systems, such as fault diagnosis, process optimisation and production-scheduling systems. This enables the production of high quality products, while maintaining cost-effective operation and minimising downtime.

Supervisory control and data-acquisition systems

Supervisory control and data-acquisition (SCADA) systems can be used to control a wide range of industrial processes and are often used to provide an operator interface for PLC-based control systems. SCADA systems are software packages designed to run on a computer workstation or industrial PC and include facilities for storing and distributing process data for future analysis.

Advanced SCADA systems also incorporate advanced control algorithms that can help operators to automatically optimise process operations and to control them. This avoids the need for frequent, manual intervention that may be required on more basic SCADA systems. Pulping sugar beet is an example of an application for this type of system. In this case, an advanced SCADA system would automatically adjust the steam input necessary to take account of the variation in moisture content of sugar beet to produce a consistent pulp. Some advanced SCADA systems also include fault diagnosis and production scheduling systems.
Energy saving opportunities

While process control systems directly account for only a small proportion of the energy used on industrial sites (typically <3%), they have an enormous influence on overall site energy use as they control the operation of all the processes, such as ovens, furnaces and reactors, and the operation of utilities, such as steam and compressed air. It is generally very cost-effective to make control improvements because the energy usage of the control system is negligible compared with the extensive energy savings that can result from the introduction of the control system.

Optimising or ‘tuning’ a process control loop involves making adjustments to the controller to change the responsiveness of the control valve to changes in the process. The optimum control valve responsiveness is the one that keeps the process control system performing at its best with minimal energy wastage. However, the performance of a control system will have a tendency to deteriorate over time due to a gradual ‘de-tuning’ of systems through constant operator override, degradation of equipment and plant failure. This means that managers are often unaware that their process control system is performing poorly. A poorly maintained process control system will consume significantly more energy than necessary because, for example, of leaks in compressed air lines to instruments and the extra valve movements needed by a poorly ‘tuned’ system.

Adopting best practice in process control can result in energy savings of between 5% and 15%, depending on the quality of existing process control systems and the nature of the process. The following figure illustrates the energy saving opportunities from improved process control on a typical industrial site:
The following sections give a step-by-step overview on how to identify and realise potential energy savings through the introduction and improvement in process control systems.

1. Investigate the current system.
2. Check instruments and regulators.
3. Ensure controls are working well.
4. Identify improvements in control.
5. Plan implementation.
6. Take action and improve controls.

Did you know?
A poorly tuned control loop can result in more energy wastage than a process using manual control.
Step one – Investigate the current system

Modern process control systems consist of complex items of computer-based equipment that must always be installed and maintained by a qualified technician or engineer. In addition, energy and production managers have an important role to play in identifying the need for control, and recognising poor control so that maintenance work and improvement projects can be undertaken.

There are a number of typical symptoms of poor control that may include:

- Controllers set to manual.
- Inefficient operation.
- Excessive variability.
- Control disturbances.
- Frequent calls for maintenance.

Controllers set to manual

Ideally, controllers should be set to automatic during normal operations, although there may be good reasons that a controller needs to be set to manual for short periods. But when an automatic control system continually develops problems or is unpredictable, operators may be tempted to override it because of a lack of confidence in its capabilities.

Counting the number of controllers that are set to manual is a good way to quickly assess the state of control on a plant. The best controlled plant have less than 2% of loops on manual control. Anything over 10% should give cause for concern that the control system may not be operating efficiently and may, therefore, be leading to energy wastage.

Process operators are less effective at routine adjustments than control systems are. Even the best operator cannot monitor and adjust the plant every second as an automated control system would do.

Control tuning could save UK industry millions

The number of ineffective process control systems was highlighted in a study conducted by a major process control supplier of 150,000 control loops at over 250 industrial sites around the world.

This survey found that only 32% of control loops were sufficiently well tuned to enable effective control. Of the remainder, 22% were in ‘fair’ condition, 10% were in a ‘poor’ condition and 36% were switched to manual. Overall, control performance across these sites varied considerably. However, even the best sites had no more than 70% of their control loops performing acceptably, while the worst sites had only 15% performing acceptably. These figures suggest there is significant scope to make energy and cost savings by carrying out simple control-system amendments.
Inefficient operation

Common symptoms of poor control are:

- Excessive or variable energy use.
- Over-purification of the product.
- Over-specification of the product.

All of these may be caused by the inefficient operation of the plant.

The energy consumption of a process varies with throughput and sometimes with product type, but the **specific energy consumption (SEC)** (energy use per unit of product) should be the same at a given throughput for the same product. Significant variations in SEC are usually an indication that improved control could save energy. For example, it is very common for busy operators to forget to reset the controls to the correct set-point following a temporary manual change. In one particular example on a paper machine, the temperature of the drying cylinders was increased to compensate for moisture streaks in the paper due to downstream blockages. Once the fault was fixed and the blockage cleared, the temperature set-point was not re adjusted, so the process continued to overdry the paper, thus wasting energy.

Monitoring the SEC of a product allows product data to be compared between different shifts as well as providing information about the system over time. This can highlight where problems might be occurring and show overall trends in performance. Monitoring may be useful in determining future energy saving actions to be taken or in reporting energy saving success stories to the workforce.

Another result of inefficient operation may be product **over-purification or over-specification**. This would be identified by comparing quality control measurements of the product with the original product specification. Over-purification or over-specification may be caused by an underperforming process-control system or one that has excessive ‘comfort margins’ built in. Once the problem had been identified, the operator would need to reset the equipment to the correct operational set-points. Over-purification and over-specification could also be caused by incorrectly set alarm limits or a poorly defined or understood product specification, leading to energy wastage.

**Case study**

Half-day of fitter’s time saves £250,000 a year

In this example from a well-respected chemical company, a processing unit had an impurity specification of 20ppm for a particular product, but the specification actually being delivered was generally <4ppm. Although the operators were producing an excellent product, energy consumption was excessive because they were not adjusting the process control set-points to align the energy input to the feed flow. The process had been running like this for five years. Reconfiguring the existing flow controllers took a technician only three hours and realised annual energy savings of £250,000.
Excessive variability

All industrial processes are subject to some variability because of changes in ambient conditions, feedstock moisture content, fuel composition and so forth. A well-designed control system will automatically adjust control settings to compensate for these natural variations. However, these adjustments may take some time to propagate through the various stages in the process and, if the control system is not tuned properly, the process operating conditions can be in a constant state of flux. This often results in inconsistent process performance or product quality.

When the external disturbance, such as a change in ambient temperature or a change in the moisture content of the raw material, can be measured, a range of simple control enhancement techniques can be used to correct for the disturbance before the process is adversely affected. If the disturbance cannot be measured, then manual adjustments should be made based on best guesses and adjusted as necessary over time. Further information on control techniques can be found in Improving the effectiveness of basic closed loop control systems (GPG346), available from the Carbon Trust, www.carbontrust.co.uk

Usually, the secret of good, economic operation is to reduce process variability and to operate close to the specification limits. This can have the added benefit of reducing energy use, leading to further savings.

The following graph refers to a paper machine dryer, where steam is used to dry the paper to a particular moisture set-point. Paper with a moisture content above 8% will be damp and unusable. A poor steam control system with lots of variability will lead the operator to operate with an excessively low paper-moisture set-point (for example, 6%) for fear of exceeding 8%. On a few occasions, the moisture will be close to the optimum 8% level, but generally the paper will be over-dried, wasting energy.

Improving the steam control system and reducing this variability allows the operator to safely increase the moisture set-point to a consistent 7.5%, reducing steam consumption and saving energy.
All process control systems are subject to disturbances, and must be adjusted to maintain stability and to prevent plant trips that occur when equipment limits are breached (for example, if filters become blocked in an air handling unit). Disturbances may be caused by sudden changes in pressure, feed rates or ambient conditions (such as air temperature) or may be due to badly tuned controllers at the lower levels of the process control system.

A well-designed, modern, process control system can be set up to automatically compensate for these disturbances before operator alarms or safety trips are activated. Therefore, this will reduce the impact of disturbances, saving energy, potential product wastage and the need for operator intervention.

**Frequent calls for maintenance**

If a process control system needs frequent repair and maintenance, then this may be a sign that its design is poor, its sensors are not robust enough for the task or it is reaching the end of its useful life. Excessive plant trips or false alarms may also be indicators of instrument failure.
Alternatively, and more often, calls for maintenance may be because operators require more training in assessing when a problem is due to an instrumentation fault and when it is something that can be resolved by the operator. For example, training could allow an operator to identify a defective consignment of raw materials that behave in an unusual way rather than diagnosing the problem as an instrumentation fault.

Similarly, the maintenance strategy itself could be the cause of problems. It is frequently the case that a reactive action is taken as a result of a breakdown, so a ‘quick fix’ is implemented rather than preventive maintenance. But if the underlying problem is not fixed, it could become a permanent issue. Furthermore, if the action taken is not documented, there may be problems at a later date when no one remembers what changes were made or why.

Instrumentation still accounts for half of all maintenance expenditure even though modern instrumentation is now more reliable than most other equipment on industrial sites.

When investigating the current status of process control, many symptoms of poor control can be identified by carrying out a walk round in the areas where there are often control problems.

Did you know?
Research suggests that operators are responsible for 40% of abnormal situations arising on industrial plant. The remaining 60% are due to equipment failure (40%) and process faults (20%).

Case study
Advanced control delivers substantial energy savings

An industrial company owned a complex, interactive plant, consisting of two large refrigeration compressors and three distillation columns, that was being run very close to its operational limits. The plant control system had been installed many years previously and was not capable of controlling operation close to the regularly changing constraints. This led to large deviations in product composition and significant energy waste.

Installation of an advanced control solution at the plant (using model-based predictive control techniques) successfully cut product composition deviation to an average of 50ppm from the desired value, compared with the 1,000ppm which would have been achieved using conventional control. In addition, energy costs were reduced over the whole range of normal operation, cutting the energy bill of the organisation by some 7%. The project paid for itself in less than six months.
Step two – Check instruments and regulators

Before any energy saving improvements can be made, ensure that all existing instrumentation and actuators are working properly. This will mean that maximum benefit is obtained from any energy saving improvements that are made. It will also ensure that performance can be measured to monitor the need for, and impact of, energy saving changes in the future.

Repair faulty instruments and valves

Often, quick-fix repairs are carried out to get the plant working again after a breakdown. However, if the underlying problem is not fixed, then the quick-fix repair may become a long-term one that continually causes problems and interferes with efficient production. Get advice from a maintenance engineer or equipment supplier on the repair and recalibration of any faulty instruments.

Poor installation practice can also seriously degrade the performance of measurement devices, control valves and their associated control loops. Examples of poor installation practice include locating terminals in inaccessible places, having excessively long impulse lines between the process and the sensor which delays responses, resulting in excessive noise (see box below) and having lines inadequately protected from frost or heat loss.

A lack of specific installation training is often the root cause of these bad practices, but time and financial pressures can also mean that corners are cut, particularly when new instruments or regulators must be installed during a very short plant shut-down.

Install new measurement devices if needed

Where disturbances are extreme enough to fall outside the range of a measurement device, the control system is effectively left blind when most adjustment is needed. This can greatly increase the amount of manual intervention required and result in energy wastage and product spoilage. For example, in the dairy industry, a level controller may not be able to measure the level of liquid in a milk tank if it has been over-filled due to an operator miscalculating or not knowing the storage capacity of a vessel. If this extreme type of disturbance happens regularly then consideration should be given to upgrading the process’s instrumentation with, for example, a high-vessel-level alarm linked to a shut-off valve so it can measure and cope with the disturbance. Also consider installing a controller that will automatically detect the disturbance at an early stage of its development and stop it evolving into a major problem.

Did you know?

The difference between accuracy and precision is often misunderstood. Accuracy is the ability of a device to give the correct value of the parameter being measured. Precision or repeatability is the ability of an instrument to give the same reading every time when the value is the same. An accurate instrument is precise, but a precise or repeatable instrument is not necessarily accurate.
Badly installed signal cables can pick up unwanted electrical interference, known as ‘noise’, from mains power cables, which distorts the measurement and control signals (see Figure 5 right), and can affect the product output. This noise can reduce controller performance and cause process operators to switch to manual control. Although flow and pressure measurements are intrinsically noisy, this level of noise can usually be filtered out. However, excessive noise can be reduced by ensuring signal cables are properly screened with earth cables. Where this is not successful, then consideration should be given to routing the signals via a modern digital Fieldbus.
Step three – Ensure controls are working well

All existing controls must be appropriately tuned and working as well as possible for a system to be efficient. Again, this will ensure that maximum benefit is gained from any energy saving measures taken.

Check control loops are not set to manual

As detailed earlier, one of the symptoms of poor control is the unnecessary overriding of automatic controls by manual operation. It is particularly important to ensure that operators are made aware of the importance of automatic control systems and the need to operate in automatic mode wherever possible. Managers should regularly check for unnecessary manual control at key times such as after shift changes, shutdowns and holidays.

Configure and tune control loops correctly

Most control tasks in the low-temperature process industries involve driving equipment that has fairly ‘linear’ characteristics. For example, the change in the temperature of an oven is proportional to the gas flow rate to the burners. Most measurement devices are also designed to have a linear response to ensure their output signal is proportional to the parameter being measured. Put simply, where there is a simple relationship between the regulator and set-point within a process, control is usually straightforward both to initiate and maintain. Where there is not a simple relationship between the regulator and set-point, special fine-tuning may be required to acquire control.

‘Non-linearities’ can occur when the response of equipment to control signals changes significantly, or when the sensitivity of the measurement device changes. Failure to tune the controller properly means it will be unreliable, respond sluggishly at times and cause plant alarms or trips at other times.

For example, the orifice-plate flow meter shows whether the correct quantity of steam at a specific temperature and pressure is being supplied to a process. This would be particularly important in the chemicals industry where some processes must be controlled to within a few degrees. Although the orifice-plate flow meter is widely used because it is inexpensive, its response does need to be ‘linearised’ before it can be used for automatic control.

Minimise time delays and dead times

No plant responds instantaneously to a change in control settings, but a badly designed or installed control system can introduce delays (or lags) that reduce the responsiveness and controllability.

Figure 6 (on page 19) shows the potential dead time that can occur in a large rotary kiln. In this case, the left-hand blue dotted line shows the ideal temperature response when a valve changes from 60% to 45% open, but a poorly positioned analyser means that there is actually a delay of approximately three minutes before the controller receives the feedback it needs to initiate the desired temperature response (the right-hand blue dotted line).

Processes like this with large dead times present a special challenge for a controller. The best thing to do for controlling this type of process is to try to reduce the dead time by moving the probe closer to the valve. If delays cannot be reduced to acceptable levels by doing this, then an expert should be consulted to advise on the introduction of advanced control techniques, such as using a model-based predictive controller.
Delays in measurement availability can also cause problems. For example, in the manufacture of French fries, the time needed to detect changes of moisture in the dryer temperature at one site was up to 95 minutes. On a fast-moving production line, this could result in many tonnes of off-specification product being produced before any correction could be made. The same problem would occur if a temperature measurement develops a large time delay – in this case the automatic control system would be likely to overshoot the temperature set-point, leading to energy wastage and production of off-specification product.

**Correct for interactions within the process**

Many industrial processes are made up of a number of integrated elements and disturbances in one part of the process can easily affect other parts of the process. Control systems should be designed to correct for these interactions.

For example, if a pressure controller and a flow controller are operating close together, then they may interact with each other making it very difficult to achieve stable control. A ‘quick-fix’ solution to this problem would be to de-tune one of the controllers, although a more permanent solution would be to separate or ‘decouple’ the two controllers.

For example, in the production of iron, coke-oven gas is produced which can be used as a fuel in other processes. In a particular instance, this volatile gas was being released from three separate ‘batteries’ and each battery was fitted with a pressure controller that controlled the release of gas into a common exhaust. This control system suffered from interactions between the three pressure control loops which resulted in pressure surges. To resolve the problem, a revised control system that decoupled the control loops was implemented. The payback period for implementing this revised control system was about six months.

**Action**

If your control loops depend on remote sampling of, for example, a product via a long pipeline, minimise your lag time by moving the analyser closer to the sampling point to improve responsiveness and control your process more effectively.

Improving the yield from a throughput is usually the most significant energy saving you can make.

---

**Figure 6 Dead time**

![Dead time Graph]

- **Valve position**
- **Temperature measurement**
- **Temperature response characteristic to a step change in feedstock to the plant**
Step four – Identify improvements in control

Having diagnosed the sources of poor control, improvement projects can then be identified. Seek out priority areas, which will have one or more of the following:

- High operating costs.
- Low energy efficiency.
- Variable performance.
- Impact on business profitability.

Identifying these areas involves careful investigation over time, but it can result in the development of a strong action plan. Following such a structured plan will ensure improvements are made in a logical order.

The table right provides relative costs and paybacks to help identify and prioritise suitable projects:

<table>
<thead>
<tr>
<th>Action</th>
<th>Capital cost</th>
<th>Payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tune controllers</td>
<td>Nil</td>
<td>Hours</td>
</tr>
<tr>
<td>Train operators</td>
<td>Nil</td>
<td>Hours</td>
</tr>
<tr>
<td>Eliminate manual control</td>
<td>Low</td>
<td>Days</td>
</tr>
<tr>
<td>Improve measurements</td>
<td>Medium</td>
<td>Weeks</td>
</tr>
<tr>
<td>Simple enhancements</td>
<td>Medium</td>
<td>&lt; 6 Months</td>
</tr>
<tr>
<td>Advanced control solutions</td>
<td>High</td>
<td>6–18 Months</td>
</tr>
</tbody>
</table>

No and low-cost projects

In the initial phases of the action plan, prioritise opportunities that are straightforward and inexpensive and that could be tackled immediately. The completion of these could even come from a maintenance budget and be incorporated into standard routine.

For example, replacing simple manual-control tasks with automated controls can yield remarkable improvements because manual control is usually far less effective than a control system. See page 21 for more detail on the advantages of automation over manual control.

Other no and low-cost measures that could be taken to save energy may be tuning or redesigning existing controllers to produce a closer-to-specification product (see page 18) and providing further training for operators (see page 14). Many of these initiatives will result in easy energy savings and have a very short payback period.
## System enhancements

Simple, properly tuned control loops are adequate for most applications but to get the best out of your process, you can improve the control by some enhancements such as: those listed below:

**Feed forward control** – feed forward control is used to anticipate and compensate for disturbances in the process. Feed forward corrects for disturbances before they affect the process, while standard feedback control only corrects for disturbances after they have affected the process. Feed forward control is often used with feedback control, but feed forward control is never used on its own.

**Ratio control** – often a particular flow needs to be proportional to another flow, for example two feeds to a reactor, or the air and gas flow to a burner. A ratio controller responds faster to changes in the other flow than would happen with standard feedback or manual control.

**Cascade control** – cascade control can be used to speed up the response of the control system, help eliminate disturbances and compensate for non-linearities. For example, it can be used to cascade the output of a furnace temperature controller to a fuel flow controller, which maintains a constant fuel flow to the furnace by preventing fluctuations in fuel pressure from affecting the furnace.

**Split range control** – split range control is a useful technique that increases the flexibility of control systems, as it allows more than one valve to be adjusted from a single controller.

**Override control** – override control provides a way of programming an alternative control action that triggers when the primary controller exceeds certain preset limits.

Further information on these control techniques can be found in the publication *Improving the effectiveness of basic closed loop control systems (GPG346).*

These initiatives, if correctly and appropriately applied, will typically save energy and have a payback period of weeks. For further information, contact an in-house control expert or an independent consultant specialising in process control if necessary.

## Larger projects

Larger projects will require senior management buy-in before they can be implemented. Projects may include installation of new PLCs, automating an entire control process or installing a model-based predictive controller. Capital costs for these larger projects are likely to be over £20k with a payback period between 6 and 18 months.
Step five – Plan implementation

Prepare the following information, which will be needed to plan implementation:

• A feasibility study of costs and savings.
• A detailed benefits and risk assessment.
• Names of the project team and potential suppliers.
• Details of a pilot project.

Feasibility study

It is usually possible to produce a reasonable estimate of the costs and benefits of a process control project following a detailed feasibility study.

Risk and benefits analysis

The cost of an improvement project can usually be calculated fairly simply, but the benefits to the business are usually less certain. To inform a sound analysis, look for the improvements which could result, such as increased throughput, improved yield, more consistent quality or more reliable operation.

The project team

For a process control project to be successful, it should involve all those who manage, operate and maintain the plant. The plant manager is usually best placed to lead the project, but a strong team would provide for consultation with representatives from the staff who operate and/or maintain the plant.

Further involvement from control engineers, the original system designer or equipment installer would be beneficial, if possible. Consultation with potential suppliers could be flagged at this point.

Pilot project

In some cases, a pilot project in one area of the site could provide the data that decision-makers require to roll out larger-scale improvements.

Fact:

If your process control system is more than 20 years old then it may be time to consider a major project to upgrade it and to realise some of the benefits of modern digital process control technology. These benefits include lower maintenance costs, reduced manning levels, improved management information, integrated production control and better safety and environmental management systems.

Process control is almost the only technology where major improvements can be made between shut-downs.
**Step six – Take action and improve controls**

When action is taken, ensure that:

- New control equipment is correctly installed and calibrated.
- Operators are fully trained in the use of the control systems and in responding to any unexpected consequences of the changes made.
- A preventive maintenance schedule is drawn up to keep controls running well.
- A wider staff awareness programme is run alongside it.

A general awareness-raising and training programme regarding energy saving may help in the successful implementation of control projects and further information on this is provided in our [Energy management guide (CTG054)](#) and [Creating an awareness campaign guide (CTG055)](#).

**Step seven – Monitor performance**

Once control improvements have been made, a regular system of checks should be set up to ensure that symptoms of poor control are identified at the earliest possible opportunity. These checks should be the same as those identified in step one to investigate current process control arrangements. This may also involve training staff to identify problems themselves, undertaking regular walk rounds of process control areas and reviewing operator logs to identify symptoms of poor control.

Also ensure that control equipment is regularly maintained in accordance with manufacturers’ instructions.

Performance targets should also be set and compared to independent measurements to ensure control systems are working. Performance targets should be communicated to operators and should be reviewed regularly to ensure they remain appropriate.
Summary

Identify where efficiency can be improved and take action. Considerable savings could be made by undertaking projects in-house, but for advanced projects, get specialist support from an equipment supplier or technical contractor.

Step 1 Investigate the current system

- Look for the symptoms of poor control such as variations in specific energy consumption, controls set to manual and production upsets.
- Carry out a walk round.

Step 2 Check instruments and regulators

- Repair faulty instruments and fix ‘sticky’ valves.
- Install new measurement devices if necessary.
- Ensure that instruments have been installed correctly.

Step 3 Ensure controls are working well

- Check if control loops are often set to manual.
- Make sure control loops are correctly configured and tuned.

Step 4 Identify improvements

- Produce a list of opportunities, considering low-cost actions, enhancements and larger projects.
- Design a plan for implementation.

Step 5 Plan implementation

- Produce a business case with a feasibility study, risk/benefits assessment and details of projects.
- Obtain support and schedule implementation.

Step 6 Take action and improve controls

- Install the control equipment correctly.
- Calibrate new instruments and verify control performance.
- Train operators and set new energy consumption targets.
- Run an awareness campaign.

Step 7 Monitor performance

- As identified in Step 1 (identify symptoms of poor control – walk round the plant, check if controls are set to manual).
- Review operator logs for symptoms of poor control.
- Review performance targets regularly.
Basic closed-loop control | A measuring device, controller and regulator working together to maintain a set-point in a process.
---|---
Blind | A term to describe the situation when disturbances are so extreme they fall out of the range of the measurement.
Cascade control | A type of control enhancement that can speed up response, to help eliminate disturbances and to compensate for non-linearities.
Controller | An instrument that compares the measured value with the desired set-point and signals a regulator to bring the measured value to the desired set-point value.
De-tuning | The deliberate adjustment of a controller away from its optimum performance.
DCS | Distributed control systems: a type of modular control system which is used for complex processes.
Disturbance | Influences or changes in the process that affect the control performance.
Feed forward control | A type of control enhancement that anticipates and compensates for disturbances.
Fieldbus | A control network used in process control industries.
Linear | The simple proportional relationship existing between process set-points and regulators.
Noise | Unwanted electrical interference from mains cables distorting signal cables.
Non-linearities | Complex relationships between process set-points and controllers requiring special fine-tuning to acquire control.
Over-purification | The production of a product to a higher level of purity than that required.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Override control</td>
<td>A type of control enhancement that provides a way of programming an alternative control action that triggers when the primary controller exceeds certain preset limits.</td>
</tr>
<tr>
<td>Over-specification</td>
<td>The production of a product to a higher specification than that required.</td>
</tr>
<tr>
<td>Payback</td>
<td>The time necessary to recover the initial outlay on an investment.</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable logic controllers — a type of sequence controller, capable of some advanced control, and easily expanded as systems get more complex.</td>
</tr>
<tr>
<td>Process control</td>
<td>The control of a process in an effective and efficient way.</td>
</tr>
<tr>
<td>Ratio control</td>
<td>A type of control enhancement that keeps one or more flow rates in proportion to another flow as conditions change.</td>
</tr>
<tr>
<td>Regulator</td>
<td>Typically a control valve, that adjusts a process flow in response to the signal from a controller.</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory control and data acquisition: a type of control system for complex processes that incorporates a software package allowing for easier visibility and data storage.</td>
</tr>
<tr>
<td>SEC</td>
<td>Specific energy consumption — the energy used per unit of product.</td>
</tr>
<tr>
<td>Sequence controllers</td>
<td>A group of controllers that govern the order in which particular operations occur.</td>
</tr>
<tr>
<td>Set-point</td>
<td>The desired, or ‘set’ value of a process variable.</td>
</tr>
<tr>
<td>Split range control</td>
<td>A type of control that allows more than one valve to be adjusted by a single controller.</td>
</tr>
<tr>
<td>Tuning</td>
<td>The process of optimising the performance of a controller.</td>
</tr>
</tbody>
</table>
Further services from the Carbon Trust

The Carbon Trust advises businesses and public sector organisations on their opportunities in a sustainable, low carbon world. We offer a range of information, tools and services including:

**Website** – Visit us at www.carbontrust.co.uk for our full range of advice and services.

- [www.carbontrust.co.uk](http://www.carbontrust.co.uk)

**Publications** – We have a library of publications detailing energy saving techniques for a range of sectors and technologies.

- [www.carbontrust.co.uk/publications](http://www.carbontrust.co.uk/publications)

**Case Studies** – Our case studies show that it’s often easier and less expensive than you might think to bring about real change.

- [www.carbontrust.co.uk/casestudies](http://www.carbontrust.co.uk/casestudies)

**Carbon Trust Advisory** – Delivers strategic and operational advice on sustainable business value to large organisations.

- [www.carbontrust.co.uk/advisory](http://www.carbontrust.co.uk/advisory)

**Carbon Trust Certification** – Delivers certification and verification services to companies and runs the Carbon Trust Standard and Carbon Reduction Label.

- [www.carbontrust.co.uk/certification](http://www.carbontrust.co.uk/certification)

**Carbon Trust Implementation** – Delivers services to business in support of implementation of energy efficient equipment and energy efficiency financing.

- [www.carbontrust.co.uk/implementation](http://www.carbontrust.co.uk/implementation)
The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

**We help to cut carbon emissions now by:**
- providing specialist advice and finance to help organisations cut carbon
- setting standards for carbon reduction.

**We reduce potential future carbon emissions by:**
- opening markets for low carbon technologies
- leading industry collaborations to commercialise technologies
- investing in early-stage low carbon companies.

[www.carbontrust.com](http://www.carbontrust.com)