Showcase

Title: **Wastewater Process Control – a UK case study**
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Date: 2013

Introduction & background information

This case study looks into the use of sensors in plant automation of activated sludge plants at wastewater treatment works in the UK. Improved control and optimisation of wastewater treatment processes offers the potential for significant savings of energy, chemicals and carbon. In recent years Advanced Process Control (APC) technologies have been developed and water companies have trialled and installed either commercial offerings or developed in-house solutions; it is anticipated that use of these systems will increase significantly in the future.

The drive within the water industry to save energy and reduce costs and minimise carbon footprint, has led to a focus on the optimisation of wastewater treatment processes, specifically the activated sludge process (ASP), which can consume up to 70% of energy used at a WwTW. Although other treatment processes are subject to optimisation, most developments have taken place on activated sludge treatment plants which is where this case study focuses.

Why is APC used for ASP?

Conventional fixed set-point dissolved oxygen (DO) feedback provides effective control of activated sludge plant aeration, but more sophisticated advanced process control (APC) which uses inputs from other sensor measurements and offers additional benefits such as reduced energy and chemical consumption and hence carbon emission as well as improved plant stability and dynamic response.

Higher oxygen transfer rates result from a reduction in the average DO concentration in aeration tanks. For example, a 20% increase in aeration rate is achieved if DO saturation is assumed to be 10 mg/l and the average residual DO is reduced from 2.5 mg/l to 1.0 mg/l. Proper DO control system design can translate such efficient use of energy into cost savings.

In addition to reduced variability in final effluent quality, the improved dynamic response of the plant under APC offers scope for reducing the headroom between normal operation levels of BOD and ammonia, and the permit conditions limit. To date, WWTW operators have not taken advantage of this, however it is anticipated that as more sites adopt advanced control, confidence in the reliability of such systems will increase and changes to control regimes will follow.

Approach and implementation

UK approaches to APC for ASP

WRc has looked at each of the three different approaches currently employed in the UK as part of a collaborative WRc Portfolio project entitled 'CP406 - Managing aeration plants to reduce energy costs and carbon emissions'. The following approaches are used with APC:

- Combined conventional feed-forward and feed-back control incorporating a process model based upon an established IWAPRC model;
- Control which utilises a predictive model of the plant built from actual observation of the plant behaviour over a representative period;
- An empirical rule-based system of control, which adjusts the DO set point according to the ammonia load using a look-up table.

Commercial systems (which in the UK includes but is not exhausted to Perceptive Engineering, STAR and Hach-Lange) use industrial PCs to run the process modelling software and to calculate the DO set points. One UK water company has implemented their control software on a PLC directly without need of a separate PC. In the price data supplied, one company has allowed £7,000 (USD 9,200) for the PC and this cost includes an outdoor housing. At some sites the industrial PC is housed in the blower building, but uses touch pads similar to a PLC rather than having a conventional PC keyboard. Perceptive Engineering used had a ruggedly mounted PC in the control room at one WWTWs, but used a conventional PC monitor and keyboard. Engineering is offering essentially a standard software product which has to be configured to the plant. Hach Lange and STAR offer control packages as modules so that the cost of the system can be scaled by the number of modules included.

Consequences of APC for ASP

It is very important that the Water Industry is confident that any future investment in APC will deliver the anticipated benefits. The savings of energy and carbon derived from improved process control can arise due to at least four causes:

- A reduced level of treatment possible due to improved stability of the treatment resulting in less variable effluent quality.
- An avoidance of over-treatment at times of low load. This is different from (a) as it does not entail any change in the target effluent quality, though it will result in a small increase in total load discharged.
- An improvement in average aeration efficiency derived from running, on average, at lower DO set-points and thereby improving oxygen transfer efficiency.
- A reduction in the endogenous load on the aeration system derived from supporting on average a smaller biomass.

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The energy savings that can be achieved by improved DO control depend on the plant loading characteristics, plant configuration and the level of instrumentation. Separately, on many sites, there is also an improvement due to upgrading of equipment such as the DO instrumentation and blowers/aerators, and there may also be a benefit simply due to increased attention, for example to maintenance of DO probes.

Anecdotal evidence from existing advanced control systems in the UK suggest that a reduction of about 20% in energy costs is typical for systems using both a feed forward and feedback function on nitrifying plants.

Whilst the main driver for installing advanced aeration control is energy saving, a significant benefit of a successful advanced control system is improved plant stability. This applies particularly to the systems which include a feed forward control function which improves the plant response to change in load. All the proprietary systems include this function, and it can be provided under an in-house developed system. However, there may be advantages for plants that are more difficult to control manually in using a proprietary system with a more complex and realistic plant model than is available under a simple SCADA/PLC system.

A detailed understanding of the impact on receiving waters over a range of operating approaches and the regulator's view and likely response to any new operating regime also need to be factored in. APC has the potential to change the underlying distribution of effluent quality. The typical effect on a distribution of effluent quality would be to reduce the amount of variability, and to raise the mean closer to the 95%ile value. The 95%ile value is important in that this is the most commonly used type of permit condition limit. The effluent permit condition limits are the prime mechanism used for the protection of receiving water quality. The Environment Agency in England and Wales is charged with ensuring receiving water standards are met and that no deterioration in quality Against the standards occurs. Faced with a fundamental change in the underlying distribution of effluent quality, the Environment Agency argues that it would have to modify permit condition limits where APC is adopted in order to maintain the existing level of environmental protection.

The UK Environment Agency, through a paper presented in March 2010, have indicated that if the widespread adoption of APC leads to operators discharging greater annual loads, through operating closer to the permit conditions limit, then permit limits may need revising downward to reduce the impact to the environment. This could undermine the anticipated benefits of introducing APC and could result in wasted capital expenditure associated with effluent quality.

Sensors used for APC

The main measurements used for wastewater process control in the UK are dissolved oxygen and ammonia, on-line nitrate is also sometimes measured..

<u>Dissolved oxygen</u>

Reliable and robust dissolved oxygen (DO) measurement is fundamental to aeration control and optimisation of the energy demanding activated sludge process used to treat wastewater. Poor DO measurement results in poor aeration control leading to variable treatment and excessive energy use.

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When applied over a whole site even relatively small errors in instrumentation readings, resulting from poor calibration, instrument drift or fouling, can add tens of thousands of pounds per year to treatment costs through excess energy use for aeration.

Dissolved oxygen measurement has benefited from a genuine advance in technology in the past few years, and there is now a generation of sensors using optical techniques which potentially offer better performance and lower maintenance than the traditional electrochemical technology. The UK water industry has been through a period of learning and evaluation using the new crop of DO monitors. The WRc Instrument User Group (IUG) has regularly discussed the pros and cons of the various commercially available instruments. The most commonly raised issues are sensor fouling, flat lining of readings, establishing which cleaning systems work, maintenance requirements and the impact of less maintenance on the instrument performance. These issues have not been resolved and currently limit the successful procurement and application of DO monitoring technology.

<u>Ammonia</u>

Ammonia may be monitored to control the supply of oxygen used for nitrification in the activated sludge process. In this application, the ammonia monitor is used as part of feed- back control to adjust the dissolved oxygen set-point and hence the rate of aeration. The ammonia concentrations from this monitoring approach can also be used to monitor consent compliance at WwTWs where the activated sludge process is the secondary stage of treatment. There is also an application for feed-forward control of aeration with the monitor positioned ahead of biological treatment.

As with all wet chemical analysers correct installation of ammonia sensors in wastewater is crucial. The UK water companies have mixed views on the benefits of the simplicity of the electrochemical probes versus the use of more complex colourimetric analysers. Probe type electrodes are generally considered more suitable for process control (optimising aeration). They work best at high ammonia concentrations. They drift and require regular calibration typically every 3 months.

<u>Nitrate</u>

Nitrate is a large part of the total nitrogen present in a final effluent, and monitoring may be needed where a site has a total nitrogen consent. Total nitrogen consent limits are predominantly either 10 mg/l or 15 mg/l as annual averages. Biological nitrogen removal is commonly used.

There are several process configurations for biological nitrogen removal and they all require a source of soluble carbon to reduce oxidised nitrogen to nitrogen gas. For activated sludge plants which recycle mixed liquor through an inlet anoxic zone to utilise the sewage soluble BOD as the carbon source, the rate of nitrogen removal can be varied by adjustment of the mixed liquor recycle rate. In principle, closed loop control of the recycle rate based on final effluent nitrogen monitoring can be applied to improve performance under varying loads. A feedback signal might also be used to vary the dosing rate of a carbon source such as methanol on plants which require a supplementary carbon source, e.g. tertiary denitrifying sand filters.

Conclusions

- There is considerable potential for the use of sensors with more advanced control of ASP in the UK.
- The performance achieved using on-line sensors is linked ot the correct installation and suitable maintenance. These two issues remain a challenge for UK water companies.
- The UK is building information on the real performance and maintenance requirements of on-line monitors through a series of trials, initially on final effluent monitoring, then DO and now on ammonia and nitrate.