Developing Renewable Energy within the Water Industry

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Introduction

Water utilities are among the most significant users of electricity. Furthermore, pumping of water is one of the major components of morning peak electricity use and so contributes to the scheduling of expensive and generally inefficient generation. While electricity prices in the UK are at historically low levels it is anticipated that prices will increase, particularly as more stringent carbon dioxide (CO_2) legislation comes into effect. As such, water utilities will be exposed to increased operating costs at the very time that Regulators expect greater efficiencies.

The benefits of renewable energy in helping deliver a low-carbon economy are well recognised. The European Union Renewables Directive and national incentives such as the UK Renewables Obligations [1] are encouraging the development of renewable energy resources. Water utilities will be expected to play their part in reducing carbon emissions through a range of measures including the development of renewable energy that can create financial benefits by reducing electricity imports.

Renewable Resources

A range of renewable energy sources are accessible to the water utility. They include, unsurprisingly, hydropower.

Hydropower

It is possible to distinguish between two types of water supply system: surface water and groundwater based. In the first type, surface water will be collected from defined catchments and would normally feature relatively large storage in the form of natural or man-made reservoirs. The water will be released as required to meet water demands and compensation flow requirements imposed by statutory environmental bodies. This raw water will tend to flow under gravity to water treatment works where it will be processed and fed on to treated water storage and from there to the consumer. Where topography places limitations on gravity feeding, pumps will be required to re-establish the necessary head. Groundwater systems will feature much of this infrastructure albeit with more emphasis on pumping raw and treated water.

Within water supply systems it is the gravity feed that offers the opportunity for developing hydropower whose potential is given by the familiar equation

$$P = \eta \rho g H Q$$

where P is power (W), η is overall conversion efficiency, ρ is the density of water, g is the gravitational acceleration, H is the head or distance through which water falls (m) and Q is the volumetric flow rate (m^3/s). As such, the water flows under gravity represent potential for hydro development. In reality, the scope for energy recovery is limited by the need to deliver water to consumers at specified pressures and the difficulty of accessing infrastructure that is often underground.

Many dams are single purpose undertakings in that they were designed and built for water supply alone. There is often significant static head behind the dam which can be tapped by installing turbines within the piping between the water intakes in the reservoir and the treatment works. Alternative systems deliver water to rivers prior to extraction at the treatment works. This means that useable pressure heads are dissipated. Installation of a turbine prior to discharge can harness the resource.

Where water is delivered direct to the treatment works, arrangements will generally be made to meet compensation flow requirements. This may involve an additional outlet from the reservoir and, dependent on the construction, it may be possible to recover some of the energy. Often compensation flow is set at the 95th percentile low flow and although this may be small relative to that delivered to the treatment works, it has the advantage of being constant which allows turbines to be rated to operate at peak efficiency at all times.

Within gravity-fed systems, there will be a need to keep pipe pressures at safe values requiring mechanisms that take pressure out of the system. These include:

- break pressure tanks which return the water to atmospheric pressure before transferring it on, and
- pressure reducing valves that actively control the opening of a valve in order to maintain the pressure at the downstream side at a defined level.

By their very nature such approaches lower the pressure by dissipating energy. A more energy efficient approach is to install hydro turbines to act as active pressure reduction devices by converting the pressure head into electricity. Clearly, the introduction of turbines in parallel with pressure reducing devices, requires fail-safe systems to allow water to bypass the generator in the event of a generator trip.

Significant energy may be recovered from raw and treated water supply systems. Some utilities have commissioned energy recovery audits of their systems and are following up on developing the more economic sites.

Wind and Others

Water utilities own significant amounts of land in the form of reservoirs, water and waste water treatment works, pumping stations and as office space. There are opportunities to harness this land for renewable energy developments.

A significant portion of this land will be in rural areas and the uplands (particularly for surface water systems) or in the case of waste water treatment plants on or near the coast. Accordingly, there may be potential for wind turbine development. These could be for individual generators located at smaller sites to arrays of turbines at larger sites. Although such arrays tend to occupy large areas of land, it is generally the case that they do not interfere with ground-based activity. A range of turbine sizes are available ranging from micro-turbines that can be sited on buildings [2] through to the current breed of 2 MW machine which stand in excess of 100 m high.

There is also scope for retrofitting or, better still, built-in to new developments, photo-voltaic (PV) panels. These could be an integral part of modern office buildings or at treatment works that have warehouse buildings. In saying that, PV cells remain costly.

Standby and Thermal Generation

Interruptions to the electricity supply would prevent the pumping and treatment of water. To mitigate this risk, standby diesel generators are commonly installed at key sites and are brought online when network supply is lost. Such units tend to be operated infrequently following network failure or periodically to test operation. It is, however, possible to use them on a more regular basis to meet peak site demands or even to export to the network or other utility-owned sites.

Clearly, diesel is petroleum-derived, is not renewable and so its use will emit CO_2. Diesel generator emissions are 75% greater than combined cycle gas turbines but 20% less than from coal-fired power stations. As such, the electricity industry fuel mix would determine if the use diesel generator raised overall carbon emissions. However, a renewable means of operating diesel sets is becoming increasingly likely through development of bio-diesel. Manufactured from vegetable oils, bio-diesel is carbon neutral and could be viable within a relatively short period, either as a standalone fuel or in a mixture with the petroleum-based fuel. Net CO_2 emissions can be reduced by between 15% for a 20% bio-diesel/diesel mix and 78% for 100% bio-diesel [3].

Further options for renewable thermal generation include the recovery and combustion of methane produced by decaying sewage waste.

Benefits

By generating electricity from energy recovery or other renewable sources the utility can reduce its importation of electricity. This has two benefits.

Firstly, the utility saves on the unit cost (MWh) of electricity defined in the supply tariff; savings are also made on the associated transmission and distribution unit charges and unit taxes such as the UK's Climate Change Levy (0.43 p/kWh).

Secondly, a major component of electricity tariffs are based on peak demand (MW) or the demand during the three highest peak period in the year (called Triad charges in the UK); where the utility is able to reduce demand from the network by lowering net demand by own generation, particularly during triad periods, then significant savings can be made. It may also be possible for the utility to export power to suppliers which will attract further revenue.

Other than the direct financial benefit, the utility is helping reduce carbon emissions which will help boost its green credentials. This is particularly important at a time of growing public interest in corporate social and environmental impact.

Impediments to Development

It would appear that there is both the renewable resource and financial and other incentives to encourage water utilities to develop the indigenous energy resources at their disposal. However, in common with many other renewable developers, progress has been slow.

Recent reports by the Royal Academy of Engineering [4] and others continue to point out that renewable energy is more expensive than conventional thermal generation, particularly combined cycle gas turbines. While these comparisons tend to ignore the environmental benefits of renewable energy and, despite criticism of traditional costing methodologies, there is no denying the fact that renewable energy is capital intensive. This clearly impacts on the investment return.

Connection of renewable generation to electricity networks is also problematic as the introduction of embedded or distributed generation alters their operation [5]. The electrical impacts are well documented and include:

1. Bi-directional power flow and the potential to exceed equipment thermal ratings
2. Reduced voltage regulation and violation of statutory limits on supply quality
3. Increased short circuit contribution and fault levels
4. Altered transient stability
5. Degraded protection operation and coordination

Where these impact adversely on electricity supply quality, mitigation will be necessary. While options exist, current commercial arrangements mean that the developer will largely bear the, often considerable, costs of implementation, harming the economics of renewable schemes.

Overall, the cost of development has been a significant obstacle to developing renewable energy. However, recent matters have begun to improve in the UK.

Supporting Renewable Energy

UK support for renewable energy originally came from the Non-Fossil Fuel Obligation which paid a premium to schemes that could be developed within target prices. While this had limited success it was superseded by the 2002 Renewables Obligation [1] and Scottish Renewables Obligation [6] which created additional benefits from the development of renewable resources.

These put an obligation on suppliers to source an increasing proportion of electricity from renewable sources which will reach 10.4% by 2010 in England and Wales and 18% in Scotland. The purchase of a unit of renewable electricity (1 MWh) will entitle the supplier to purchase a Renewable Obligation Certificate (ROC) from the generator. These can be bought and sold within the ROC market with the value varying with supply and demand. Alternatively, suppliers not reaching their obligation level may opt to pay a ‘buyout’ penalty which stood at £30/MWh at inception and is index-linked. Overall the renewable generator will receive the base cost of the electricity plus the value of the ROC. The base cost is generally the wholesale price – currently £22/MWh – which is significantly lower than the ROC buyout price or the current ROC market value of £45/MWh. The ROC significantly improves the economics of renewable installations. In saying that, project financed schemes tend to suffer from lenders’ overly pessimistic valuation of ROCs. With balance sheet financing, as might be the case with water utilities, this should be less of a problem.

Problems with current connections policies for distributed generation are well known and UK practice is likely to change over the next few years [5]. Rather than require developers to finance, upfront, the costs of network changes necessary for accommodating their generator, network operators will be able to upgrade the network and collect use of system charges instead. This will improve project economics significantly.

Conclusions

The drive for low-carbon energy supply has led to ambitious targets for the use of renewable energy. As a major user of electricity and, with opportunities to develop hydropower and other renewable sources at its disposal, water utilities can make a major contribution to meeting renewable targets. This paper explored the scope of renewable energy developments within the Water Industry, the issues that can constrain it, and the developments and measures that may assist in delivering a low-carbon future.

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References

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