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Reactor decommissioning in a deregulated market

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Introduction

Deregulation of the electricity markets in North America and Western Europe has had many profound effects on the electric utilities and the nuclear industry. Deregulation has led to cost transparency, increased competition, and a drive by the utilities to reduce costs in order to maintain market share and margins.

The combination of economic and political pressure has led to the threat that large numbers of nuclear stations may be closed early. However, recent developments in the US have seen a move to life extension, as a combination of a perceived energy shortage, concerns over CO_2 emissions and a desire by the utilities to make the best use of existing capital take effect.

Cost transparency focuses attention on all factors affecting the cost of generation. This includes not only the obvious costs associated with new fuel, reactor operations, spent fuel, and plant life extensions, but also "back-end" factors such as waste management and decommissioning costs.

In order that the economics of the life cycle of a nuclear plant can be fully assessed, there has always been a need for a clear understanding of the costs of decommissioning, as well as a demonstration of how achievable the decommissioning activity is in practice. As such, there is a degree of uncertainty in the minds of the utilities as they assess the costs of their liabilities and make the necessary provisions via the segregated funds and on the balance sheet. The need to be seen to be financially prudent, and a responsible liability holder, has led to a tendency to over-provision. As well as adding to the cost of nuclear generated electricity, and therefore weakening its competitive position, the uncertainty in the cost of decommissioning is seized upon by the industry's detractors, and is often cited by lobbyists as another example of the nuclear fuel cycle not being truly closed.

This paper seeks to summarise BNFL's experience with regard to recent developments in reactor decommissioning and demonstrate how commercial projects in crucial areas of strategy development, project implementation and site restoration are beginning to reduce the risks and uncertainties associated with this important aspect of the nuclear power generation industry.

Although the reactor decommissioning market cannot yet be regarded as mature, the key elements of strategy development, waste treatment, dismantling and delicensing have been separately demonstrated as achievable. Together with the implementation of the right organisation, and the developing technology, the risks are being reduced. As more decommissioning projects are delivered, the risks will be reduced further and the confidence of the regulator in the process will improve. This paper sets out to demonstrate this viewpoint.

Strategy Development

Utilities around the world have investigated a range of strategies including both prompt and deferred dismantling.

BNFL, as an owner and operator of its own fleet of nuclear (Magnox) reactors, has conducted extensive engineering studies to allow a thorough analysis of competing decommissioning approaches. Items considered include issues such as safety, environmental impact, political and regulatory factors, engineering complexity, and cost. Some of these issues have been assessed objectively (such as calculation of a dose rate, or an economic cost), but others have been addressed subjectively (for example, the regulatory position or public opinion at a future date). Formal decision analysis techniques have then been used to compare and contrast a range of options and to help to select the preferred solution which was to adopt the deferred dismantling approach. The results of these studies have been used to gain regulatory acceptance of the decommissioning plans for BNFL facilities.

Other utilities have, for a variety of reasons, adopted faster, more aggressive decommissioning strategies. As yet there are relatively few cases of completed "prompt" decommissioning projects, but examples can be found such as the Fort St. Vrain project in the US. However, several international working groups (sponsored by the EU, IAEA and NEA) are developing standardised decommissioning cost models. In addition, strategy and cost development services are now available to utility clients on a commercial basis, based upon experience gained from commercial decommissioning projects. For example, BNFL now has considerable experience of a range of decommissioning strategies, both on its UK sites, and on a commercial basis for other clients, for example WAGR (UKAEA), KNK (Karlsruhe) and Big Rock Point (Consumers Energy). Through a process of continuous feedback and improvement, BNFL is constantly updating its strategic approaches to decommissioning, refining its cost database and adding to its capability for successful decommissioning methodologies and equipment. As a result, BNFL has a proven methodology that can be applied quickly and efficiently to new reactor types and locations and now has significant international experience of delivering similar studies on a commercial basis to operators and national waste management organisations.

Experience of Decommissioning Operations

Magnox Reactors – Waste Treatment and Deferred Dismantling

As indicated above, the deferred dismantling, or 'Safestore' strategy has been adopted for the BNFL Magnox plants. This comprises the removal of the fuel, retrieval of all operational waste, and dismantling of contaminated and non-contaminated plant external to the Reactor Buildings. The Magnox reactor core, pressure vessel, and bio-shield are then sealed for a period of at least 70 years in order to take advantage of radioactive decay and to await the availability of a suitable waste disposal location for core materials.

Decommissioning of the BNFL Magnox plants at Berkeley, Trawsfynydd and Hunterston in the UK is proceeding in line with the 'Safestore' strategy, while decommissioning planning for the plants at Hinkley and Bradwell is well advanced. The first three stations have been defuelled, and programmes for the packaging of the accumulated operational wastes are well advanced.

Extensive deplanting and demolition of redundant buildings is being carried out in order to minimise the ongoing maintenance requirements on each site. Plant being dismantled includes fuelling machinery, gas circuits, heat exchangers (at Berkeley only), fuel storage pools, fuel handling equipment including cranes, manipulators and active handling cells, and conventional equipment. Buildings being demolished include turbine halls, workshops, and most ancillary plant and office buildings. The bulk of the waste materials are being decontaminated to below the free release levels thus permitting recycling, or, in the case of concrete rubble, disposal to local landfill sites. Other low active wastes are being disposed of to the BNFL owned and operated Low Level Waste (LLW) disposal facility at Drigg. Intermediate Level Wastes (ILW) are being stored on site pending decisions on the development of a UK disposal facility.

WAGR Sellafield, UK – Prompt Dismantling

The Windscale Advanced Gas Reactor (WAGR) was a prototype unit for the UK's commercial Advanced Gas-cooled Reactor (AGR) programme with a primary function of developing and testing high temperature fuels. The reactor first went critical in 1963 and was finally shut down in 1981. It had a design output of 100 MW (thermal).

BNFL is now managing the dismantling and decommissioning of the WAGR reactor having secured a fixed price contract for this work from the UKAEA, who remain the owner and the site licence holder for the station. The dismantling is being undertaken in a series of campaigns, one for each of the major components, such as gas manifold, neutron shield, graphite core, internal support structure, and the pressure vessel itself.

Remote handling equipment, including manipulators, hoists, transfer and viewing equipment has been installed to carry out the work. In addition a waste route has been set up to assay and encapsulate the dismantled components in self shielding boxes for storage on site as ILW, or disposal at the LLW facility.

In order to dismantle each main area of the reactor, a specific methodology, and the necessary tools, have to be developed and tested for use with the manipulators and other remotely operated equipment.

To date, operational waste and experimental 'loop tubes' have been removed from the reactor channels, and the gas manifold cut up and dismantled. Removal of the neutron shield is the next campaign to commence.

The remotely operated dismantling techniques used include remote viewing, plasma arc and oxy-propane powder injection cutting, hydraulic shearing, and grinding, together with a series of and lifting devices to secure and remove the components from the reactor vault.

The dismantling work is now 2 years into a 6-year-long programme. Several unexpected problems have been encountered and overcome during this period, and the project remains on target for successful completion in 2006.

Big Rock Point, Michigan, USA – Prompt Dismantling

Big Rock Point is a 75MW(e) BWR, located on the east shore of Lake Michigan that was initially used as a research reactor for fuel types, as well as commercial production. It closed in 1997.

The scope of BNFL's contract comprises decontamination of the primary circuit, the removal of the major components (emergency condenser, poison tank, steam drum, and reactor vessel), and decontamination and demolition of all buildings and structures.

The reactor vessel is being removed complete with the bulk of the internals to the Barnwell disposal site. The vessel measures 10m high and 2.75m diameter. A container has been designed for the transfer, and NRC licence approval has been received. The reactor head is to be disposed of separately.

To date the spent fuel has been stored in the pool, the reactor vessel characterised, the primary circuit chemically cleaned (300 curies removed), and the turbine removed.

Fort St Vrain, Colorado, USA - Site Delicensing and Restoration

The Fort St. Vrain facility was a high temperature gas cooled reactor owned by the Public Service Company of Colorado, USA. This project represented the first commercial reactor of its size to be decommissioned in the USA under a fixed price contract.

The reactor was shutdown on 1981 and the decommissioning project led by Westinghouse[1] and Morrison Knudsen[2] commenced in 1992. The project was delivered ahead of schedule and to specification in 1997 when the site licence was terminated. The site was then redeveloped for a Combined Cycle Gas Turbine plant.

A feature of the decommissioning was the development of the techniques and equipment for, and the implementation of, the underwater dismantling of the reactor.

University Research Reactor (URR), Manchester, UK - Site Delicensing and Restoration

BNFL is responsible for the decommissioning of a number of research reactors in the UK. The University Research Reactor (URR) near Manchester has been decommissioned and the site de-licensed. Significantly, the process for this total site de-licensing has established some of the principles that would be applied if part or all of the commercial plant sites were to be de-licensed. In addition two other reactors are being decommissioned - a Triga reactor at Humberside for ICI, and the Scottish Universities Research Reactor.

Lessons Learned

The approach to decommissioning, and the techniques used, are in essence straightforward, and there is no reason why it should not be managed in the same way as any other project. However, as with other projects, experience is essential in order to reduce the risks and costs. This embraces the adoption of a definitive strategy, the necessary planning and preparation, setting up the right organisation with defined responsibilities, and knowledge of the right technology for the job with access to the appropriate specialists.

Organisation

The key to a successful project is the organisation.

One option is to utilise the existing plant operations team both to manage, and to a certain degree, to carry out the decommissioning. This has the advantage that the human resource is already there, and is familiar with the plant. The disadvantage is that operations staff have no decommissioning experience, and retain an ‘operations’ mentality towards discharging the work.

However, there is evidence to suggest that co-operation between the utility (with its site and regulatory experience and vested interest in discharging the liability) and decommissioning experts with clear prior experience of organising and discharging decommissioning projects is the most effective combination.

Therefore the BNFL approach is to set up a dedicated and experienced Decommissioning Project Team. This is headed by a Project Manager who is responsible for all decommissioning work on site, and reports to the Plant Manager who is the ‘client’ and retains responsibility for all regulatory and site safety issues.

[1] Westinghouse is now part of BNFL plc
[2] Morrison Knudsen is now the Washington Group International

BNFL, with their rolling programme of decommissioning plants, has established their core decommissioning organisation. This infrastructure is used to resource the decommissioning teams for each of their own sites, in addition to work for external clients.

Operations staff can be transferred onto the decommissioning team, but training is required in order to reflect the change in discipline and attitude.

In brief, decommissioning is not compatible with an operations mentality. All non-essential equipment and systems should be dismantled and removed as soon as possible in the project. This reduces operations and maintenance costs and minimises the possibility of staff being distracted from the core task of decommissioning by routine operations tasks which are no longer necessary.

Strategy and Planning

The first step towards a successful decommissioning project is to develop a clear strategy that is both acceptable to the Regulator, and is achievable in terms of programme and cost.

This must then be followed by the appropriate survey and preparatory work in order to specify the task, and then to select the most effective approach while minimising waste handling by applying knowledge of the range of techniques available. Added to this must be the experience to cope with any unforeseen circumstances that arise.

The starting conditions and desired outcomes must be clearly defined and the decommissioning operations correctly sequenced, such that upstream activities are not causing problems downstream. If the end point should change, then a re-evaluation should be done to ensure that the approach originally selected is still appropriate.

Once the overall strategy has been defined for a particular plant, or series of plants, the development work should be carried out by the Decommissioning Team for that plant. This means that the Decommissioning Manager and his team should be mobilised well before the plant closure occurs, ideally no less than two years in advance. The structure of the team will evolve as the focus changes from addressing the methodology and planning through to implementation and project management.

Contract Strategy

The dedicated Decommissioning Team is responsible for all decommissioning work, and hence manages all contractors engaged in these activities.

The strategy is to minimise the number of contracts by placing them for each of the major disciplines only, such as plant and waste characterisation, decontamination, dismantling/size reduction, packaging and demolition.

Where specialist services are required to support these major contractors, such as tools and rigging, remote handling techniques, shielding etc., they would be the responsibility of the major contractors themselves to buy in directly.

This approach facilitates better work specification and control, in comparison with the placement of many small packages of work, which inevitably would result in increased interfaces (organisational/contractual) and require extra resources to manage.

Technology

The main activities associated with decommissioning are decontamination, dismantling, demolition, size reduction, assay, and packaging. These are not necessarily as sophisticated as the technologies used for the construction of the plant, and need only to be adequate to the point of achieving the desired objective of decommissioning the site. However, it is important to use proven methods which will provide for secure planning and costing rather than theoretical approaches relying on advanced technology to deliver what is only a potential cost reduction.

The lesson of experience is the ability to select techniques that are the simplest, but fit for purpose, in order to adequately achieve the task, no more or no less. It is also important, however, to still recognise where a specialist approach is required, and where shortfalls may occur.

Summary and Conclusions

Reactor decommissioning is not yet a mature service. Currently it is a ‘bespoke’ activity, and a fully developed ‘package solution’ will only be available in the longer term.

An example of this is the BNFL Magnox closure programme, where all 18 currently operational reactors have now been designated to close between 2002 and 2012. This will enable a fully planned and resourced process to be set in place using a dedicated organisation.

Decommissioning projects are being discharged successfully, and considerable ‘hands on’ experience exists over a range of reactor types and decommissioning strategies.

This experience is contributing to an increasing information base which is leading to a growing confidence with regard to identifying the unknowns and uncertainties associated with reactor decommissioning, and managing the risks.

This, in turn, is providing more accurate data for closing out the nuclear life cycle costs, and increasing regulatory confidence. The reliability of this information will therefore increase in the short to medium term as more plants are decommissioned and further experience gained.