3rd January 2012

Foreword

The Japanese earthquake and ensuing tsunami of March 11th 2011 were of a serious scale and proportion, and the people of Japan continue to experience some extraordinary challenges. EDF Energy, along with our colleagues in EDF in France, are unified in solidarity with our colleagues in Japan and the global nuclear community in facing the challenges posed by this situation in relation to the Fukushima accident. We are united by the need to react, and act, in a highly responsible way, understanding and learning from the facts and acting on them with humility and leadership.

The events at Fukushima will have a significant impact on the way the nuclear industry operates in years to come. At this stage, we recognise that the UK nuclear industry will need to carefully assess and make appropriate changes in several key areas including:

- Continuing to improve open, transparent and trusted communications and relationships with key stakeholders,
- Enhancements to on-site resilience to the effects of major events,
- Reviewing and improving local protection systems for key plant areas,
- Provision of off-site emergency back-up equipment that can be readily connected to the plant,
- The potential impact of abnormal natural events on local and national infrastructure,
- Particular consideration to be given to the level of self sufficiency of the sites following extreme events,
- Emergency planning arrangements to respond to extreme situations.

More generally, we will consider how we will deal with the personal aspects for the workers and public in terms of the physical, emotional, cultural and societal impact of a massive disruption to infrastructure.

We see understanding and responding to the lessons learned from the events at Fukushima as a key step in continuing to support the maintenance of high safety standards, and this is an approach we wish to support, including the stated intent to conduct this process in an open and transparent manner.

EDF Energy will ensure that this event provides a positive input to future operation of our plants in the UK. EDF Energy is determined to be supportive throughout this process and is committed to playing an active and leading role in the lessons learnt exercise to ensure our plants will continue to be operated safely and contribute to making the UK a low carbon economy.

Humphrey Cadoux-Hudson

Managing Director, Nuclear New Build

EDF Energy

EDF Energy is one of the UK's largest energy companies and the largest producer of low-carbon electricity. A subsidiary of the EDF Group, one of Europe's largest power companies, we generate around one sixth of the nation's electricity and employ around 15,000 people. We supply gas and electricity to more than 5.5 million business and residential customer accounts and are the biggest supplier of electricity by volume in Great Britain.

Our existing nuclear business, EDF Energy Nuclear Generation Limited, operates eight nuclear power stations (15 reactors) in the UK with a combined capacity of almost 9,000 megawatts – electricity that is vital to the UK economy. Our Nuclear New Build programme, being delivered by EDF Energy NNB Generation Company Limited (NNB GenCo), is tasked with the delivery of a new generation of nuclear plants at Hinkley Point in Somerset and Sizewell in Suffolk, to provide a vital contribution to the UK's future need for clean, affordable, secure energy.

EDF Group is the leader in nuclear energy and safely operates the largest fleet of civil nuclear power plants in the world. It has built and operates 58 nuclear power stations in France and it is currently building a 'third generation' nuclear power station at Flamanville in Normandy, similar to those planned for Hinkley Point and Sizewell.

In its nuclear activities, EDF Energy has partnered with Centrica, which has a 20% stake in the company's eight existing plants and in the project carrying out development work for nuclear new build. Centrica also has the option to take up to 20% stakes in each of the four planned plants.

1. Introduction

Events at Fukushima

On the 11th March 2011, Japan's east coast was hit by a magnitude 9 earthquake, the largest recorded in Japan, and then about an hour later by a very large tsunami. The Japanese earthquake and ensuing tsunami were of a serious scale and proportion, and the people of Japan continue to experience some extraordinary challenges.

The tsunami inundated the Fukushima Daiichi nuclear site, located in the Tohoku region in eastern Japan. It is clear that Fukushima Daiichi was a serious nuclear accident, with an eventual Level 7 rating on the International Nuclear and Radiological Event Scale (INES) scale, a tool for communicating to the public the severity of reported nuclear and radiological incidents and accidents. This is only the second time in history that any incident has been given such a rating.

Not everything is known about the detailed circumstances and contributory factors, and may never be, given the state of the Fukushima Daiichi site after the tsunami. A description of the current understanding of events following the earthquake and tsunami, are provided in the report produced by the UK's HM Chief Nuclear Inspector on lessons learned to-date from the events at Fukushima.[1]

EDF Energy is determined to learn all the lessons from this event in Japan to ensure this knowledge is incorporated into our existing fleet of nuclear power stations and the proposed new reactors planned in the UK.

The response to Fukushima

Within days of the events at Fukushima, the UK Government requested that the HM Chief Nuclear Inspector, Dr. Mike Weightman, prepare a thorough and independent report on the implications of the situation in Japan and the lessons to be learned. The interim report[2] and final report[1] were published in May and October 2011 respectively, and provided a series of recommendations for Government, regulators and the nuclear industry to consider and adopt. In parallel with welcoming Dr Weightman's statement re-affirming that UK nuclear facilities have no fundamental safety weaknesses, EDF Energy has embraced all relevant recommendations and provided regular updates on work being undertaken by its business in adopting these into its operations.[3]

Following the events at Fukushima, the European Commission declared that "the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk assessment." This assessment was referred to as a 'Stress Test' and its scope was compiled by the European Nuclear Safety Regulators Group (ENSREG)[4]. It was decided that this assessment would cover all nuclear plants under construction, in operation or in the process of decommissioning, and would include a variety of triggering events (such as those experienced at Fukushima, e.g.

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[1] HM Chief Inspector's Final Fukushima Report
[2] HM Chief Inspector's Interim Fukushima Report
[3] http://www.hse.gov.uk/nuclear/fukushima/submissions/index.htm
[4] ENSREG is an independent, authoritative expert body, composed of senior officials from national nuclear safety, radioactive waste safety or radiation protection regulatory authorities from all 27 Member States in the European Union and representatives of the European Commission.

earthquakes and flooding) taken to their extreme and potentially occurring simultaneously.

All the operators of nuclear power plants in the European Union were asked to review the response of their nuclear plants to these extreme situations and produce a report detailing the findings. These reports would be first reviewed by the national nuclear regulators (which in the UK is the Office for Nuclear Regulation (ONR)), and then summarised in a UK National Report for submission to the European Commission by the end of December 2011.

NNB GenCo was also asked by the ONR to prepare a response to the ENSREG Stress Tests as a prospective licensee. Although the plant is not yet under construction, it was considered appropriate to apply the Stress Tests at this stage of the design process. ONR have confirmed that the outcomes of the NNB GenCo Stress Tests will not be reported in the UK National Report, which focuses on existing facilities.

This paper summarises the outcomes of the NNB GenCo Stress Tests review, focusing on the potential resilience enhancements to our planned UK new build programme.

2. Assessing our design in the UK

NNB GenCo has selected the third generation European Pressurised Reactor (EPR) for its new build programme in the UK. The EPR is a Pressurised Water Reactor whose design combines familiar and proven technology, with the latest performance and safety innovations. The EPR is a modern reactor design which is very different in design compared with the Boiling Water Reactors used at the Fukushima Daiichi nuclear site, and it features additional safety features in comparison. A total of four EPR reactors are currently being built in Finland, France and China.

NNB GenCo intends to build four new EPR reactors in the UK, based on the generic design currently being assessed by the ONR and the Architect Engineer. This will comprise of two reactors at Hinkley Point and two at Sizewell; these sites are referred to as Hinkley Point C (HPC) and Sizewell C (SZC) respectively. The design for the UK EPR is still under development and neither HPC nor SZC has entered the construction phase of the project. NNB GenCo plan to commence construction at HPC before SZC. To enable development of an EPR at the HPC site, a number of activities are underway which must be complete prior to construction starting. These include the approval of planning permission for the development of the HPC site, submission of the pre-construction safety reports, and granting of a nuclear site licence for the HPC site. The same steps will also need to be carried out for SZC. NNB GenCo has appointed an Architect Engineer (EDF DIN) to support the production of the design; EDF DIN is also responsible for the design of the EPR at Flamanville, France, which is now under construction. It is anticipated that the two designs will be very similar, as they are based on the same underlying technology.

All operating nuclear power stations in the UK are built and operated to meet high standards of safety, security, environmental protection and waste management. By law, a site cannot have nuclear plant on it unless the operator has demonstrated its capability to the ONR and subsequently been granted a nuclear site licence. The UK regulatory regime sets out high safety standards expected of a licensee of a nuclear site. EDF Energy Nuclear Generation Limited is currently the license holder of eight nuclear sites, and in July 2011, NNB GenCo applied for a site licence for HPC.

In 2007, the ONR and Environment Agency set out proposals to assess new nuclear reactor designs, in advance of any proposals to build a nuclear power station in the UK. The process became known as the “Generic Design Assessment” (GDA). GDA allows the generic safety, security and environmental aspects of a new nuclear reactor design to be assessed. The EPR generic design is currently undergoing the GDA process and further information on the many safety features of the EPR generic design can be found on the EPR GDA website.[5]

ONR have requested that the relevant lessons learned from the events at Fukushima are incorporated into the EPR design via the GDA process. Any changes identified to the EPR generic design will be incorporated into the design produced for HPC and subsequently SZC. As part of the Stress Tests process, EDF DIN has reviewed the Flamanville design against the Western European Nuclear Regulators Association (WENRA) Stress Tests specification[6], and this has been undertaken with the involvement of NNB GenCo. The results of this review are therefore a key reference

[5] http://www.epr-reactor.co.uk/scripts/ssmod/publigen/content/templates/show.asp?P=331&L=EN
[6] This Stress Tests specification preceded the ENSREG Stress Tests specification but the scope was very similar.

source for the NNB GenCo Stress Tests in the absence of a developed design for HPC. The NNB GenCo Stress Tests also uses existing reports and studies specific to HPC, to take account of extreme events which could occur at the site.

In addition, as a prospective nuclear site licensee with future responsibility for the safety of a nuclear installation, NNB GenCo has undertaken its own independent review of the EPR design to ensure that the safety and robustness of the plant has been fully explored in the UK context. The results of this work have also been included in the NNB GenCo Stress Tests report.

3. Resilience of our plants

EDF Energy has a responsibility to protect people from risks originating from the activities associated with its operations. EDF Energy is responsible for reducing this level of risk as low as reasonably practicable (ALARP). The ONR provides guidance on how a licensee should demonstrate the reduction of risk.[7] The methodology to ensure that the risk from the design of plant is ALARP is widely used in the nuclear industry. This iterative process of identifying ways to lower risk is key to the nuclear safety culture in the UK and is a core value of EDF Energy. The assessment of risk takes account not only of the potential consequences of an accident scenario but also the probability of occurrence. Typically for extreme hazards – such as the risk from an earthquake or flooding – a one in ten thousand year event is considered. For the UK, the risks from earthquake and flooding are significantly lower than that at Fukushima Daiichi.

The probabilities of the extreme events put forward in the ENSREG Stress Tests are extremely low and would not normally be considered as credible within the design basis of a nuclear plant. The UK HM Chief Nuclear Inspector has confirmed that no fundamental UK safety principles need to be reviewed as a result of the events at Fukushima.[1] However, in partnership with ONR, UK nuclear licensees have identified the concept of 'resilience' to account for further considerations to extreme events. The process of considering resilience is similar to the method in which ALARP is approached by the nuclear industry in the UK, but with additional considerations given to the lessons learned from the events in Fukushima and reviews of relevant best practices. In its Stress Tests assessment, NNB GenCo has applied the guidance developed with ONR and the UK nuclear industry, to identify the potential resilience enhancements for the UK EPR.

[7] http://www.hse.gov.uk/nuclear/operational/tech_asst_guides/tast005.htm#purpose

4. Outcomes of the assessments

NNB GenCo's primary focus is to ensure nuclear safety through control of essential systems. The overriding objective is to prevent events that could lead to a radiological release that could threaten the public, employees at the plants, or the environment. Potential hazards that could affect the plants, including extreme events, are also assessed and measures are taken to maintain safety. The nuclear power stations that EDF Energy operates and is looking to design are or will be designed to be safe and reliable, with safety systems that do or will provide defence in depth. This means that a number of different systems perform the same function, so that the safety of the plant does not depend on any single feature.

All of the analysis performed since the events at Fukushima has confirmed the safety of the EPR design. The design is safe against flooding and earthquakes, as well as the additional extreme events considered as part of the Stress Tests assessment. The events in Japan have, however, clearly demonstrated that an extreme event can have consequences over a very wide area, damaging existing infrastructure (power lines, roads etc) and overwhelming emergency services. During such an event, a nuclear power station must be maintained in a safe state with limited reliance on off-site help. All nuclear sites in the UK all have Emergency Plans in place to respond to any emergency situation. The EPR is designed to ensure that it can be maintained in a safe state for a significant period, without reliance on off-site infrastructure and emergency support. However, to protect against extreme events, such as those experienced at Fukushima, there are a number of enhancements being considered by NNB GenCo to provide additional resilience to the EPR. These potential resilience enhancements have been identified from the reviews of the EPR and HPC design, together with learning from the events at Fukushima. These proposed enhancements will ensure that in the unlikely event of an extreme event, the EPR design will continue to be resilient for the duration of the event

The Executive Summary of the HPC Stress Tests report, containing the results of the assessment is published alongside this summary.[8] This provides further technical detail on all the potential resilience enhancements identified for further consideration. The type of potential resilience enhancements identified for the UK EPR can be broadly grouped into the themes discussed below.

<u>Earthquake</u>

The current understanding is that all the reactors at Fukushima safely shut down following the earthquake and it was the flooding from the resultant tsunami which caused the significant damage to the plant and infrastructure in the surrounding area.

The UK is not generally associated with significant earthquakes. However, around twenty to thirty earthquakes a year are large enough to be felt by people and many smaller earthquakes also occur. The largest known UK event recorded is the 1931 Dogger Bank event of magnitude 6.1. Research suggests that the largest predicted earthquake in the UK is around magnitude 6.5. This is significantly smaller (around 300 times) than the earthquake experienced at Fukushima which was magnitude 9. The EPR is designed to safely withstand seismic activity at a higher level than that predicted in the UK.

[8] UK EPR: Response to EU "Stress Tests" Chapter 0: Executive Summary [*www.edf-energy.com/stresstest*]

The EPR planned for HPC is designed to comfortably withstand earthquakes at levels greater than the maximum level anticipated in the UK. However, NNB GenCo will ensure that for the resilience enhancements identified as appropriate for the HPC design, these are also able to withstand earthquakes where relevant.

Flooding

At Fukushima, the barriers provided in the event of sea-borne flooding were not sufficiently high to protect the site from being inundated by the extreme wave height resulting from the tsunami, and consequently the site was flooded. Flooding does also regularly occur in the UK. It can arise from a wide variety of sources which are broadly divided into two main categories; those arising from extreme sea conditions and those arising from other sources (i.e. river flooding, rainfall and flooding from artificial sources). All operating nuclear power stations are located at coastal or estuary locations, and hence must be protected from both flood risk scenarios.

For extreme sea conditions, studies have been conducted (which include the latest forecasts on climate change), to calculate the most extreme wave heights which could occur at the HPC site. For the UK, the risk of a significant tsunami is much lower than Japan, and the largest waves will be caused by storm conditions in combination with high tides. At HPC, the key safety features of the plant will be constructed above this wave height and protected with robust sea defences.

In terms of flood risk from other sources, such as extreme rainfall and river flooding, these hazards are characterised by the presence of a layer of water on the site. Nuclear power stations in the UK are designed to withstand such events. For HPC, work in this area is ongoing and the various means to provide further defence in depth against these kinds of events are still under development (i.e. drainage systems). The proposed solutions will be included in the HPC design.

The EPR design at Hinkley Point C is safe against flooding events originating from extreme sea conditions. However, NNB GenCo will consider additional flood protection measures to ensure that key buildings and facilities on site are protected from flooding if an extreme event were to occur.

Back-up electrical supplies

Although the purpose of a commercial nuclear power reactor is to generate electricity, it also requires a large amount of power to operate safely and efficiently. At Fukushima, for units 1 to 5, all emergency diesel generators (back-up supplies) were lost as a result of the flooding from the tsunami. After the battery supplies were exhausted there was no other immediately available means to supply power to the reactor support systems, until off-site power was restored several days later.

In normal operation, the power required to operate a nuclear reactor is drawn from the national grid or from the power generated by the plant itself. In the event of a loss of off-site power (from the national grid), the EPR design has four large emergency diesel generators for each reactor, each of which can safely operate all plant and equipment for a period of 3 days (without further diesel fuel being made available).

At HPC, in the unlikely event that all four emergency diesel generators fail, in addition to losing off-site power, there are two further ultimate diesel generators, which, although smaller, can operate the key safety systems for the reactor. Each can provide a further 24 hours of power (without further diesel fuel being made available).

In the event of a complete station blackout (from loss of off-site power and all the diesel generators), there are batteries which can operate the key safety systems for up to 12 hours. The batteries provide a supply to limited plant functions, indications and emergency lighting. It should be noted that the loss of all power supplies is considered very unlikely.

The EPR design at Hinkley Point C provides back-up electrical power against the loss of off-site power for at least 3 days. To further enhance the duration of on-site power for key safety systems, NNB GenCo will consider options to transfer fuel to the ultimate diesel generators from the emergency diesel generators, to extend their operation (in the event that fuel supplies can not be brought to site). NNB GenCo will also consider options to extend the duration of the batteries by providing additional stationary or mobile power sources on site.

Back-up water supplies

To ensure safe and efficient operation, nuclear power stations require continuous cooling. For the EPR, pressurised water is used as the primary coolant to transfer heat away from the reactor. This heat is then used to turn water in a secondary system to steam, to power the turbines and generate electricity. The steam from the turbine is then cooled in a condenser, using large quantities of water usually drawn from the sea or a large body of water, before the process is repeated. A more detailed explanation of the operation of a nuclear reactor can be found on the EDF website.[9]

The heat generated by the reactor is determined by the nuclear reaction taking place within the fuel in its core. For an EPR, in normal operation, the heat from the nuclear reaction is sufficient to generate 1600MW of electricity. However, even when the nuclear reaction is shut down, there is still significant heat contained within the core of the reactor. This 'residual heat' must be removed to ensure the reactor core temperature stays at a safe level. Four independent cooling systems, using electrically driven coolant pumps, continue to circulate the water to remove the residual heat when the reactor is shut down.

In a station blackout situation, where there is loss of off-site power and all the diesel generators stop functioning (i.e. necessary electrical sources to help maintain some of the necessary functions onsite), the coolant pumps will not operate, the residual heat will not be removed, and the temperature within the reactor will begin to rise. If this situation is allowed to continue, then water levels within the reactor can drop, and lead to the nuclear fuel being uncovered and consequently damaged.

Under normal operations, spent fuel, even when it is removed from the reactor, also produces residual heat, albeit at a lower level. Consequently, spent fuel taken from the reactor is stored in a spent fuel pool, covered with water, to assist with cooling and to help shield personnel from harmful radiation. The water level in this fuel pool must be topped up to ensure that the fuel remains covered.

During station blackout, the electrical pumps to top up the pool would no longer function. In parallel, the electrical pumps used to circulate the water to the heat

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[9] http://www.british-energy.com/pagetemplate.php?pid=314

exchanger would also stop functioning. If this situation is allowed to continue, then water levels within the spent fuel pool can drop, and lead to the nuclear fuel being exposed and potentially resulting in heat being released into the environment.

At HPC, in the unlikely situation where off-site power and the emergency diesel generators are lost, cooling of the fuel can be maintained using an emergency system. This is powered by the ultimate diesel generators and has sufficient water to continue to cool the reactor for 2 days. Other water tanks can then be used to top up this system, extending the period it can operate (providing fuel is available for the ultimate diesel generators) for approximately 9 days.

The EPR design at Hinkley Point C provides back-up water supplies to remove residual heat from the reactor core for approximately 9 days. To further enhance the resilience of back-up water supplies, NNB GenCo will consider the provision of an additional water supply to be used for the removal of containment heat. NNB GenCo will also consider options to re-supply the spent fuel cooling pools using this additional water storage.

Management of nuclear accidents

A nuclear accident is defined by the International Atomic Energy Agency as "an event that has led to significant consequences to people, the environment or the facility. The UK has had nuclear power since 1956, and since then there has been one nuclear accident, that took place at Windscale in 1957, which was categorised on the International Nuclear Event Scale (INES) as an 'accident with wider consequences'. This happened within a military reactor which had a very different design to those used in the UK's civil power reactors.

A nuclear licensee is expected to have the necessary arrangements, resources and infrastructure to face any situation, whether incidental, accidental or any other serious event. Those already working on site when an extreme event occurs will be prepared for the necessary short term actions. The operating crew will be assisted by a team on site in an emergency control centre. Emergency exercises will be carried out regularly to allow operators and technical support to build up the necessary skills to be confident they can manage in a crisis situation. It also aids in understanding some of the events that can occur and the actions required to manage such a situation. These actions will be laid out in emergency operating procedures to ensure a rapid and robust response.

The events at Fukushima have highlighted the need to account for the psychological impact of such a severe event on personnel, and further consideration will be given to this.

The means used in normal operation for control of radiological conditions and radiological risks to people would still be operational but adapted to conditions which may occur during a serious accident. The usual radiological protection procedures will also be in place but it is possible that interventions in radiologically hostile conditions (over and above normal exposures) might be required for preservation of life. Stocks of iodine tablets are maintained in the event of a radiological emergency.

As part of the Stress Tests assessment, the safety features of the plant are assumed to be progressively challenged, leading to a nuclear accident situation being considered. There is recognition that the organisational requirements for dealing with a nuclear accident will be different to those during normal operation, hence there will be procedures and processes in place to re-organise as soon as possible following a nuclear accident. This will allow the event to be dealt with in a more efficient way and maintain the safety of staff as far as possible. Although emergency arrangements have not been finalised at this stage, NNB GenCo are working with EDF Energy Nuclear Generation Limited, to consider the emergency arrangements required at the Hinkley site. At this stage, the Stress Tests results have highlighted a number of potential resilience enhancements to be considered for the EPR design and NNB GenCo's emergency arrangements.

To further enhance the resilience of on-site power, NNB GenCo will consider the provision of a high power mobile emergency generator which can be connected at fixed points for the re-supply of electrical power to the reactor and fuel buildings.

NNB GenCo will consider the provision of a mobile pump to introduce water in to the reactor building, to help remove residual heat and ensure that the nuclear fuel remains covered.

NNB GenCo will consider the introduction of communication systems on site which can function during a station blackout (without electricity).

NNB GenCo will review and consider whether sufficient instrumentation will be available to the emergency response team to monitor the condition of the plant during a severe accident.

NNB GenCo will consider whether there are advantages in increasing the flexibility of the existing safety features of the plant, to transfer fluids and power between them.

NNB GenCo will consider carry out a number of studies to ensure that there are no areas of the plant which are susceptible to a build up of combustible gases or pressure in a serious accident, and identify resilience enhancements to mitigate this issue.

NNB GenCo will ensure that our accident management procedures take account of the learning from Fukushima and any future resilience enhancements implemented.

5. Next Steps

The Stress Tests assessment has shown that the proposed EPRs at HPC are robust when put under stress from extreme scenarios, even for situations far beyond what could ever be plausible in the UK, and confirmed that the plants would continue to be safe. The potential resilience enhancements which have been identified to further increase the defence in depth will need further consideration over the coming months, to ensure they complement the existing EPR safety systems and emergency procedures. Any resulting changes will be subject to internal and independent review processes, agreement with the ONR where appropriate, and then subsequent incorporation into the HPC and SZC design.

In parallel, NNB GenCo will continue to embrace the findings of the UK's HM Chief Nuclear Inspector's report. Where relevant, NNB GenCo will incorporate the findings of the Stress Tests into its programme of work to address Dr Weightman's recommendations. The response to his final report will be provided by June 2012.

EDF Energy have and will continue to demonstrate that it applies rigour in gaining all learning from the current events in Japan and applying this to existing operational plants as well as new build projects, as part of the process of continuous improvement. Continuous improvement is part of the safety culture throughout EDF Energy, who invest on average over £300 million each year in its plants to ensure they remain at the forefront of nuclear safety. This same principle means that lessons learned from Japan will not be lost and ensure that the safety of the UK nuclear industry is enhanced still further.