Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Analysis of Recent Trends and Important Factors of CANDU Plant Lifetime Management

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1. Introduction

The design life of Wolsong Unit 1 is 30 years, and it has been operated for 22 years. Wolsong Unit 1 was designed by AECL(Atomic Energy Canada Limited) which also designed Pickering, Darlington, Bruce and Point Lepreau nuclear power plants. The pressure tubes of Pickering Unit 1,2 were replaced in 1985, and the pressure tubes of Pickering Unit 3 were replaced in 1989 and the pressure tubes of Pickering Unit 4 were replaced in 1991. New Brunswick electric power has decided to refurbish Point Lepreau nuclear power plant which has the same operation age as the Wolsong Unit 1. The refurbishment of Point Lepreau nuclear power plant includes replacement of fuel channels and feeder pipes. KEPRI had performed Wolsong Unit 1 plant lifetime study phase 1 and had carried out PSR(periodic safety review) of Wolsong Unit 1[1]. Since last year KEPRI has been performing Wolsong Unit 1 plant lifetime study phase 2, and this will be continued until the year 2007. This plant lifetime management study phase 2 of Wolsong Unit 1 is to support KHNP(Korea Hydro & Nuclear Power Co. Ltd) that is planning Wolsong Unit 1 refurbishment. Refurbishment means large scale maintenance, and the plant shutdown period for many refurbishment works would be more than one year.

In this study, it was surveyed that what are the very recent trends of CANDU plant lifetime management, and that what would become the important factors in CANDU plant lifetime management in connection with these recent trends.

2. Recent Trends of CANDU plant refurbishment

In connection with the CANDU plant refurbishments, two big decisions were made in this year. One is Point Lepreau Nuclear Power Plant decision, and the other is Pickering Nuclear Power plant decision. The details are following.

2.1 Point Lepreau Nuclear Power Plant

In the end of July 2005, CANADA New Brunswick Province Premier Bernard Lord announced that the Province of New Brunswick will proceed with the refurbishment of Point Lepreau with Atomic Energy of Canada Limited (AECL) as the general contractor without the support of the federal government. His Cabinet has received and accepted an unanimous recommendation from the Board of NB Power to move forward with the refurbishment. The decision came after many months of discussions, negotiations and deliberations with a wide variety of stakeholders, potential partners and other interested parties[2].

In early July 2005, Canadian federal government made the decision not to invest in New Brunswick by investing in the refurbishment of Point Lepreau, although Premier of Province of New Brunswick asked the federal government to support the nuclear industry in his province because AECL is federal government corporation.

Commissioned in 1983, Lepreau's CANDU-6 reactor provides New Brunswick with 635 megawatts of electricity, 30 per cent of its energy requirements. It was commissioned in 1983 at a cost of $1.44 billion and was scheduled to operate until 2008.
Completion of the detailed engineering and procurement will begin this summer with completion expected by March 2008. The construction of temporary facilities and waste storage will begin in April 2006. The planned maintenance outage will start in April 2008 and will be completed by September 2009. The estimated cost of the project, including the purchase of replacement electricity, is $1.4 billion[2].

2.2 Pickering Nuclear Power Plant

In the middle of the August 2005, CANADA Ontario Power Generation (OPG) President and CEO Jim Hankinson announced that OPG has decided not to proceed with the refurbishment of Pickering A Units 2 and 3. Instead, it will devote its resources and expertise to maximizing the performance of its ten existing nuclear units. OPG's Board of Directors accepted management's recommendation that the refurbishment of Units 2 and 3 not go ahead and advised the Ontario Government of its decision[3].

For several months OPG has studied the economics of the Pickering A Units 2 and 3 return to service, including third party reviews, aiming at operating its assets as efficiently and as cost-effectively as possible.
In the end, OPG doesn't see a sound business case for returning Units 2 and 3 to service. The expertise in nuclear operations and the knowledge gained by returning Units 4 and 1 to service was used in maximizing the performance of these two units, and the other eight units at Pickering and Darlington stations. OPG's nuclear units are important for Ontario as they produced close to 30 per cent of the power used by the province last year[3].

OPG reassured both workers in OPG's nuclear division and the communities in the Durham Region

that the decision does not reduce the relevance of nuclear power to either Ontario Power Generation or to the province. To this end, studying the case for extending the life of the Pickering B station, and ultimately Darlington as well, is a key element of OPG's plan for the future.

The nine nuclear units that OPG had in service last year produced 42.3 terrawatt hours of electricity, 4.6 TWh more than OPG's nuclear production in 2003. Nuclear output was 40 per cent of OPG's total electricity production last year. These improvements have carried through to this year as the nuclear units have had outstanding performance in the high-demand winter and summer months. OPG returned Pickering A Unit 4 to service in 2003 and Unit 1 is now undergoing commissioning. The refurbished Unit 1 is expected to be in service in October at a projected cost of about $1 billion. Units 2 and 3 have been maintained in a safe shutdown state since December 1997. Over the next two years the fuel and heavy water will be removed from Units 2 and 3 and the units will be put into a long-term lay-up state.[3]

3. The important factors in CANDU plant lifetime management

Up to now, two big decisions made in CANADA were introduced, as it is shown in the previous section, the decisions were made based on economic issues. And so therefore, these recent two trends tell us that economic aspect is one of the important factors in CANDU plant lifetime management.

One more important thing to consider is that the cause of the large scale maintenance, the grand refurbishment, should be managed continuously in plant lifetime management. The cause of the large scale refurbishment has turned out to be fuel channel elongation. Therefore, the most important thing in CANDU Plant lifetime management is continual monitoring of the fuel channel elongation.

Fuel channel elongation can be represented by the following four equations.

$$\dot{\varepsilon}_d = \dot{\varepsilon}_{thermal} + \dot{\varepsilon}_{creep} + \dot{\varepsilon}_{growth}$$

$$\dot{\varepsilon}_{thermal} = [K_1 C_1^d \sigma_1 + K_2 C_2^d \sigma_2^2] \exp(-Q_1/T) + K_3 C_1^d \sigma_1 \exp(-Q_3/T)$$

$$\dot{\varepsilon}_{creep} = K_c K_4(x) C_4^d(x) \sigma(x) \Phi [\exp(-Q_4/T + K_5)$$

$$\dot{\varepsilon}_{growth} = K_g K_6(x,\varphi t) C_6^d(x) \Phi \exp(-Q_6/T)$$

where,

$\dot{\varepsilon}_d$: strain rate

K_1, K_2 : high temperature(≥570K) thermal creep constant

K_3 : low temperature(< 570K) thermal creep constant

$K_4(x)$: function of microstructure variable

K_5 : constant determined by experiment

$K_6(x,\varphi t)$: function of fluence, location, aging time

C_1^d, C_2^d : constant determined by stress indices and creep

$C_4^d(x)$, $C_6^d(x)$: constant determined by stress indices

K_c : radiation creep constant

K_g : radiation growth constant

Q_1, Q_3, Q_4, Q_6 : activation constant

σ_1, σ_2 : effective stress for thermal creep (MPa)

$\sigma(x)$: effective stress for radiation creep (MPa)

T : temperature (°K)

Φ : fluence (n/m^{2}s, E>1MeV)

t : radiation time(sec)

Above four equations have become the governing equations determining the life of CANDU plant after construction. Next to this fuel channel life management, CANDU Plant lifetime management is to select the refurbishment items. The refurbishment items means, for example, replacement of a certain pump, or a pipe, or a valve, or any kinds of large scale maintenances which cannot be done during a normal plant outage, because the refurbishment outage would be long enough to replace fuel channels and the duration of the refurbishment would be more than one year. In order to selection proper refurbishment items economic aspects, safety aspects, and power production aspects should be put into consideration.

4. Conclusions

In this study, two recent cases were surveyed. One is Point Lepreau case and the other is Pickering case. From these recent trends analysis, economic aspect has turned out to be the important factor that determines plant lifetime. Pickering determined to shut down and not to refurbish Unit 2, 3, while Point Lepreau determined to extend its life and refurbish its plant. The root cause of the refurbishment is the fuel channel elongation and this fuel channel elongation management has become the most important factor in lifetime management. Fuel channel replacement takes long time which is more than one year and during this long period of plant shut down, lots of plant maintenance works can be done. And the final important factor is the selection of the large scale maintenance works that could be done during this refurbishment period, and selection work must consider economic, safety, and power production aspects.

REFERENCES

[1] KEPRI, “Wolsong Unit 1 Plant Lifetime Management Study (I), 2003.
[2] NB Power, “www.nbpower.com”, 2005
[3] Ontario Power, “www.ontariopower.com”, 2005.