Simulative Study on battery back-up time extension

Korea Institute of Nuclear Safety

Department of Nuclear Safety

Sungbaek Park

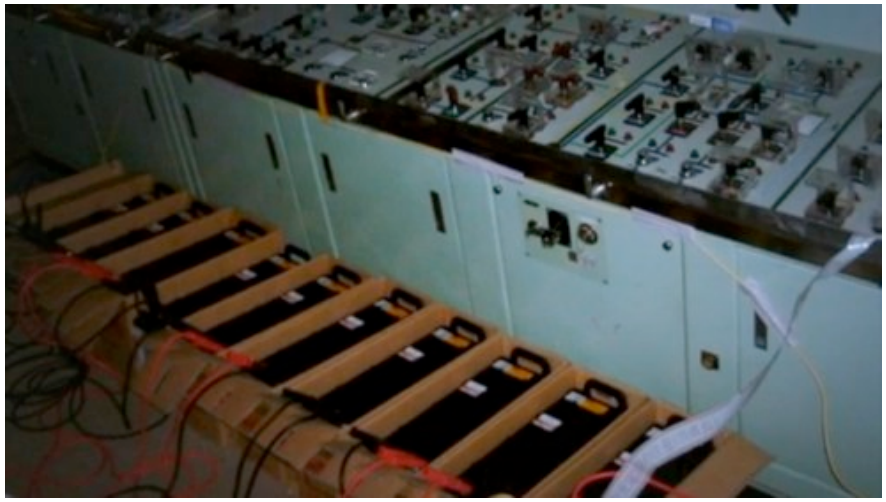
Contents

Introduction

Background

- The Fukushima Daiichi disaster illustrated the fact that the electric power is critical to the safety of nuclear power plants(NPPs). To strengthen integrity of electrical power supply, many countries have extended battery back-up time by means of load shedding which disconnect portion of battery loads or larger battery installation.
- In Korea, the regulator required minimum 8 hours of battery back-up time and the licensee prepared back-up time extension measure with load shedding. To do so, operators should declare SBO and disconnect all the non-essential loads within designated time.

[Picture of Fukushima daiichi 3]



[Car batteries rigged together to power gauges]

Introduction

Background

- In other countries, some NPPs have battery back-up time extension procedures with removing a single battery train from service then restoring that battery train when the opposite train battery has depleted. This method has advantage of maximizing battery back-up time.
- This study presents battery sizing calculations of various alternatives in combination of removing battery trains and load shedding. Among them, the most appropriate alternative is deduced considering back-up time extension and operation convenience.

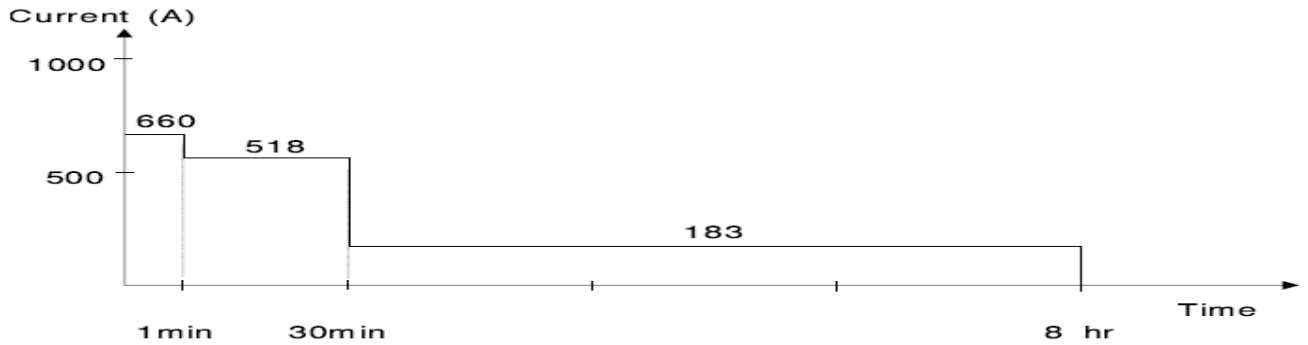
> -IAEA TECDOC-1770 5.2 SBO Design Consideration
> Station batteries that have been shown to supply power for at least 8 to 12 hours with load shedding. Run time or DC power availability can be extended for longer duration with deep load shedding procedures or removing a single battery train/division from service then restoring that battery train/division when the opposite train/division battery has depleted.
>
> - NUREG CR-7188 3.3 Sequence 2 Load Profiles EBR-4
> To maximize battery runtime, the strategy employed at this site is to run the Train A battery first and minimize the load on the Train B battery initially. When the Train A battery is approaching depletion, the alternate Train B instrumentation would be re-energized from the Train B battery.

[Extractions from technical reports on battery back up time extension]

Study Cases

Simulation Basis

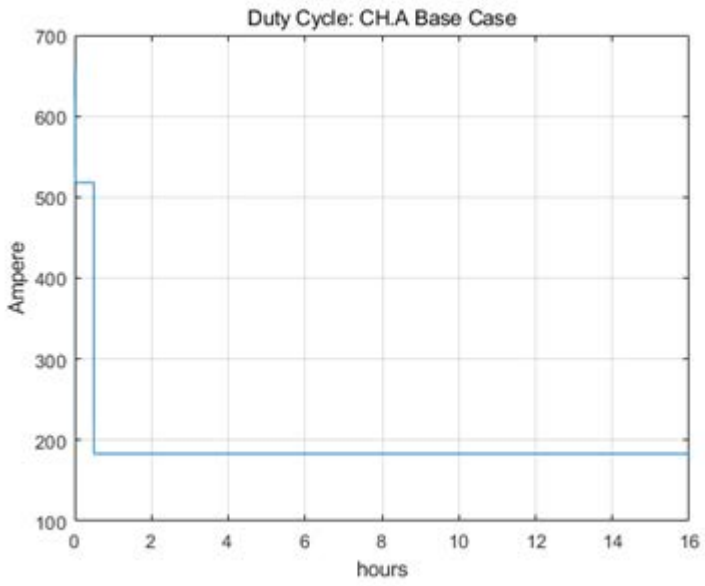
- This study is based on the battery sizing calculation of channel A in a KHNP type nuclear power plant which is re-calculated reflecting load shedding after 30 minutes of SBO. Calculation result was 2,305 AH (1,708 AH before applying factors) and 2,800 AH battery was chosen.
- Correction factors
  - Aging factor based on battery replacement at 80% of rated capacity
  - Temperature correction factor based on the lowest room temperature.
  - Design margin not included
  - Capacity rating factors (Kt factor) from the table provided by the battery vendor which has maximum Kt factor at 999 min. (Some of Kt factors are interpolated for model duty cycles.)

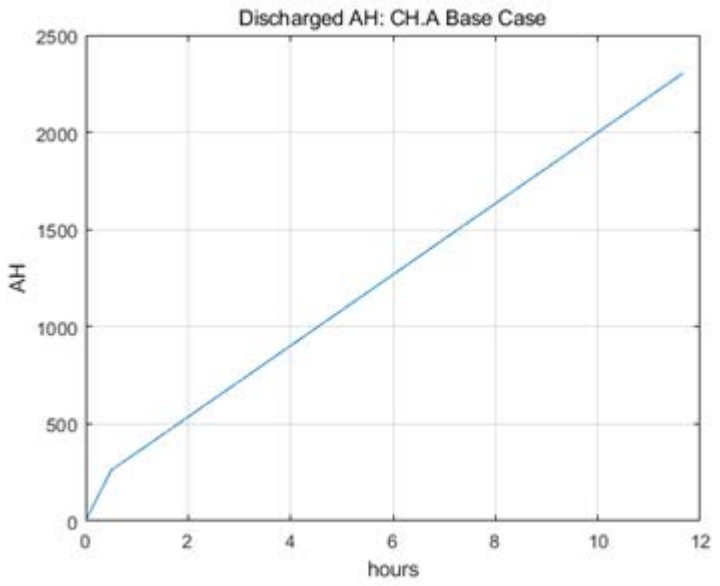


[Class 1E channel A Duty cycle]

Study Cases

- **Base Case**
  - ✓ Base Case shed loads after 30 minutes from SBO. This is same as original procedure except it lasts until 16 hours.

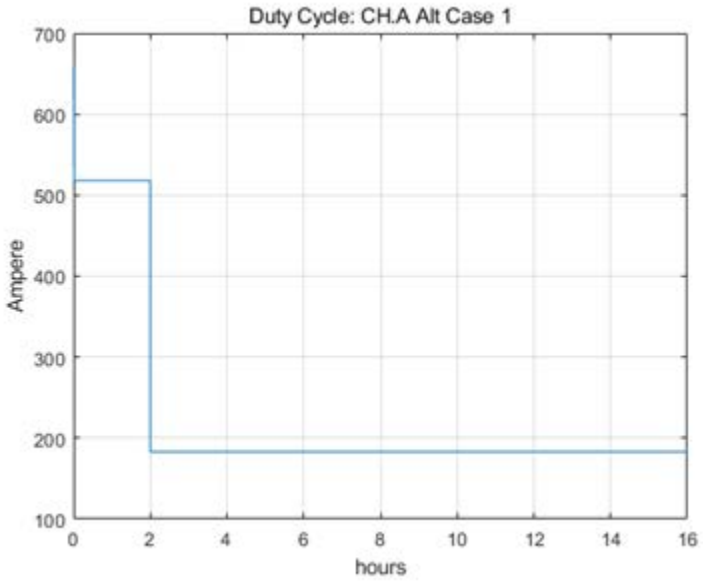


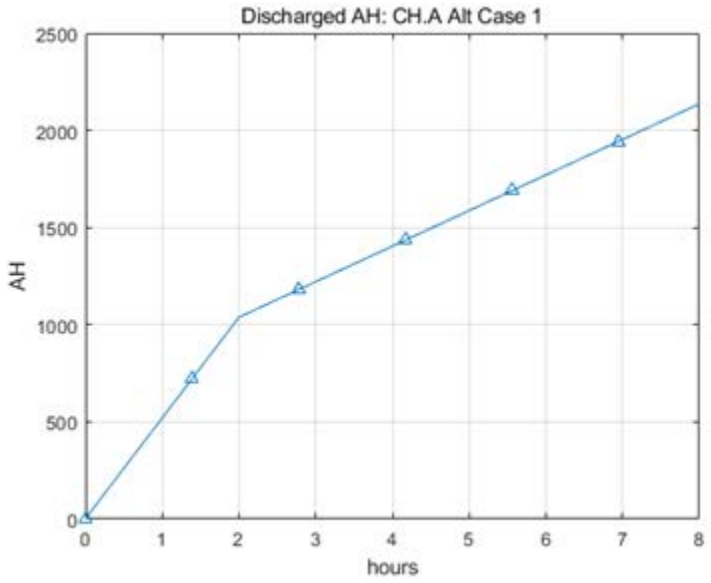


[Class 1E channel A Duty cycle - Base Case]

Study Cases

- **Alternative Case 1**
  - ✓ Alternative Case 1 shed loads after 2 hours from SBO and continue discharge for 16 hours.

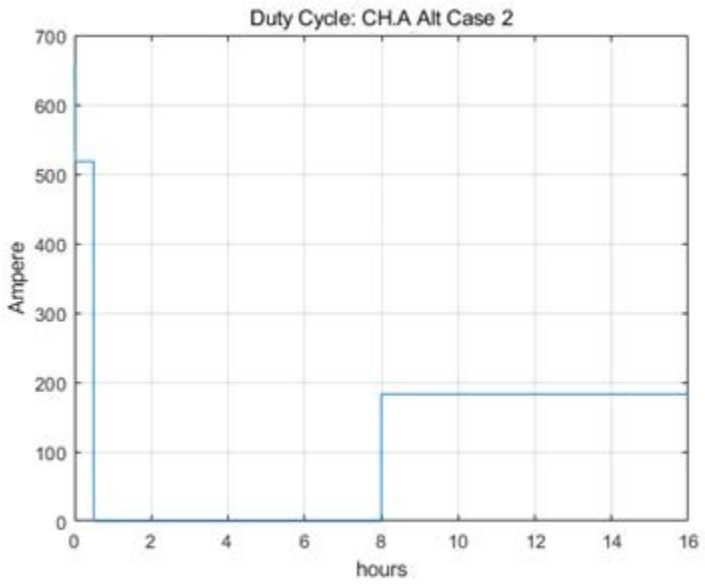


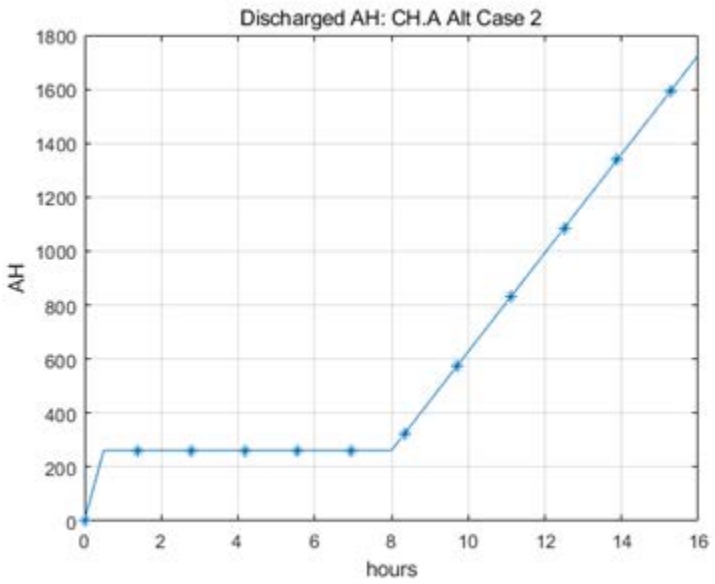


[Class 1E channel A Duty cycle - Alt Case 1]

Study Cases

- **Alternative Case 2**
  - ✓ Alternative Case 2 remove the battery after 30 minutes from SBO, restore it at 8 hours after SBO and continue discharge until 16 hours after SBO.

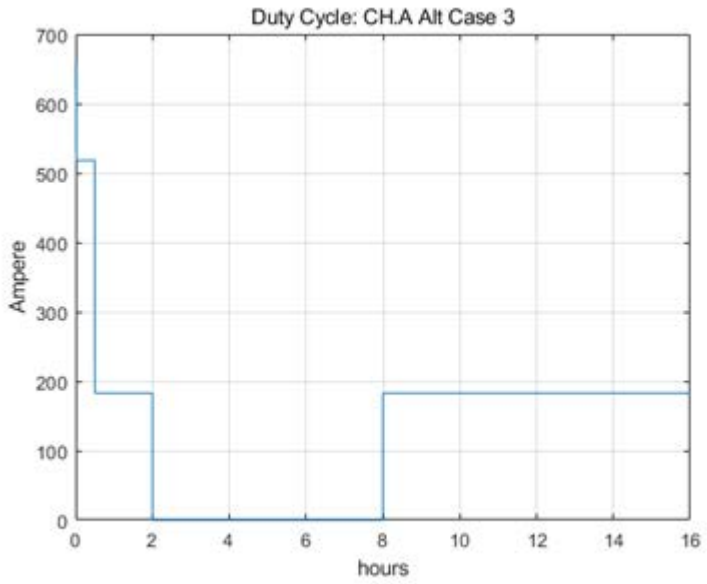


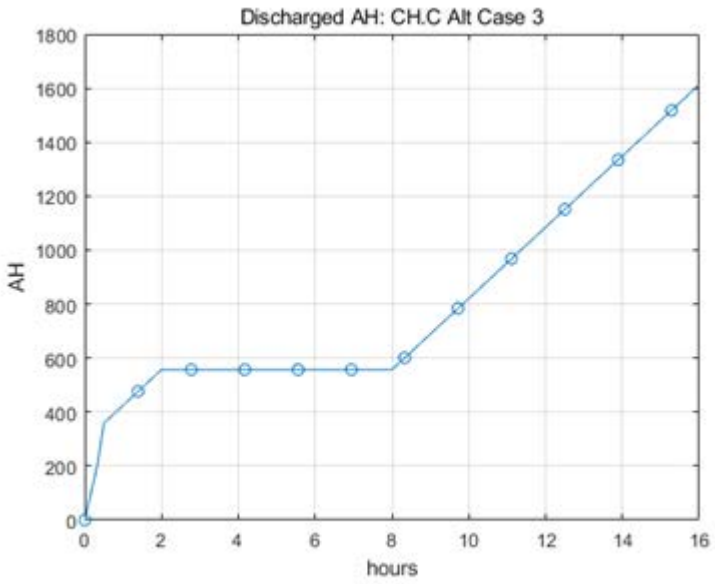


[Class 1E channel A Duty cycle
- Alt Case 2]

Study Cases

- **Alternative Case 3**
  - ✓ Alternative Case 3 shed loads after 30 minutes from SBO, remove the battery after 2 hours from SBO. After 8 hours from SBO, restore the battery and continue discharge until 16 hours after SBO.

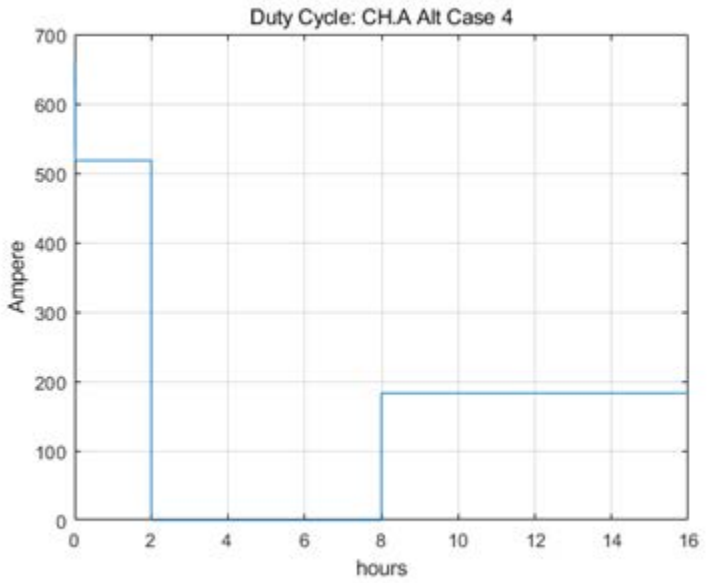


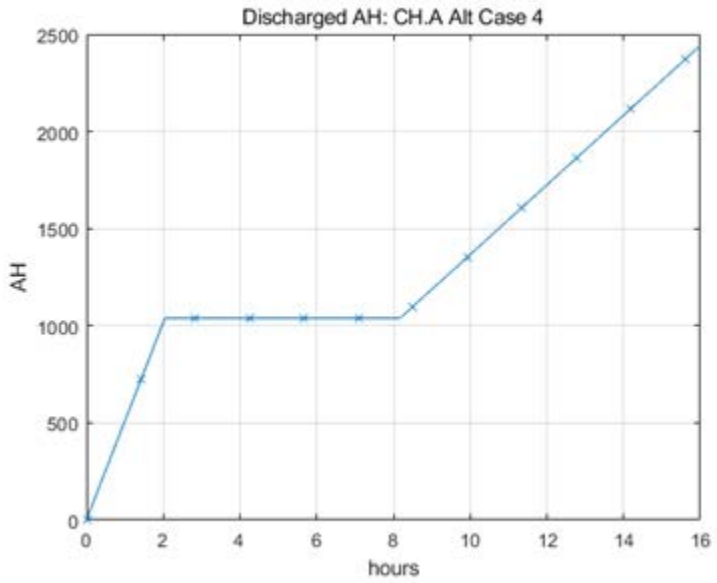


[Class 1E channel A Duty cycle - Alt Case 3]

Study Cases

- **Alternative Case 4**
  - ✓ Alternative Case 4 remove the battery after 2 hours from SBO, restore it at 8 hours after SBO and continue discharge until 16 hours after SBO.





[Class 1E channel A Duty cycle - Alt Case 4]

Study Result

Calculation Result

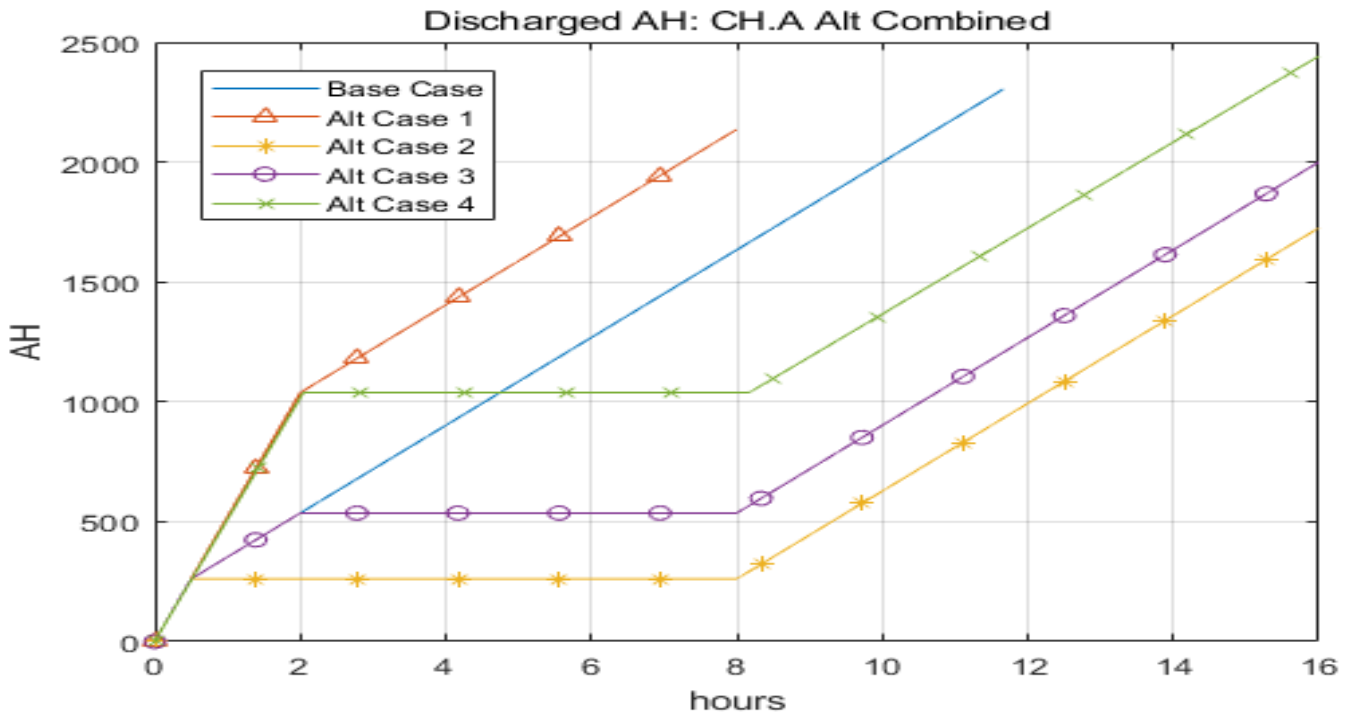
- ✓ While all the cases met current regulatory basis, available discharge time of Base case, Alt Case 1 & 4 was shorter than 16 hours with installed battery capacity.
- ✓ Alt Case 1 showed shorter back-up time although it has relatively longer time to shed loads then Base Case.
- ✓ Alt Case 2 showed the longest back-up time, however removing battery channel after 30 minutes of SBO seems excessive measure considering possibility of mobile generators and emergency power recovery.

	Base	Alt 1	Alt 2	Alt 3	Alt 4
Minimum Required Capacity [AH]	3,277	3,639	2,264	2,262	2,824
Available Discharge Time [min]	700	480	>999	> 999	940

[Calculation Result – all Cases]

Study Result

- **Calculation Result**
  - ✓ Among Alt Case 3 & 4, Alt Case 4 has longer time to shed loads and long enough back-up time.
  - ✓ Thus, Alt Case 4 seems the most suitable alternative among the cases.



[Discharged AH – all Cases]

Conclusion

- In this study, alternatives were set up considering possible delay of ELAP declaration, manual operations, and deployment of mobile generators.
- Battery sizing calculation results are compared with different load shedding time and removal of the battery channel.
- Among the cases, removing the battery after 2 hours of SBO, and restore after 8 hours seems to have advantages both in additional conservatism with increased battery back-up time and operational convenience.

- It is recommended for the utilities to establish battery back-up time extension procedure considering the importance of safety rated batteries, uncertainty of beyond design basis events and possible restoration of power supplies.
- We suggest to establish optimum battery back-up time extension procedure including battery channel disconnection and restoration as a possible approach for each NPP type.

THANK YOU