Transactions of the Korean Nuclear Society Virtual Autumn Meeting
December 17-18

Simulative Study on battery back-up time extension

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1. Introduction

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.

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.

2. Study Cases

2.1 Simulation basis

This study is based on the battery sizing calculation of channel 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 is chosen. Fig.1 shows duty cycle diagram of Class 1E channel A battery of one of the KHNP type nuclear power plant.

Correction factors in the calculation was aging factor based on battery replacement at 80% of rated capacity, temperature correction factor based on the lowest room temperature. Design margin is not included because revised duty cycle is not for design based event and additional duties are not included in the original battery calculation. Capacity rating factors (Kt factor) are applied 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.

Alternatives were set up considering delays of ELAP declaration, manual operations, and deployment of mobile generators. Loads to shed in this paper are same as original procedure and removing loads are same as disconnecting the battery channel from the system. Utilizing battery channel removal, battery back-up time can be maximized if it restores after the other channel battery depletion. In this study, battery restoration is assumed after 8 hours from SBO and maximum duration is assumed 16 hours.

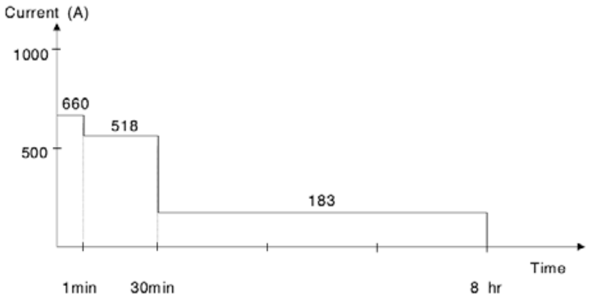

Fig. 1. Class 1E channel A Duty cycle.

2.2 Base Case

Base Case shed loads after 30 minutes from SBO. This is same as original procedure except it lasts until 16 hours. Fig. 2. shows duty cycle of the Base Case.

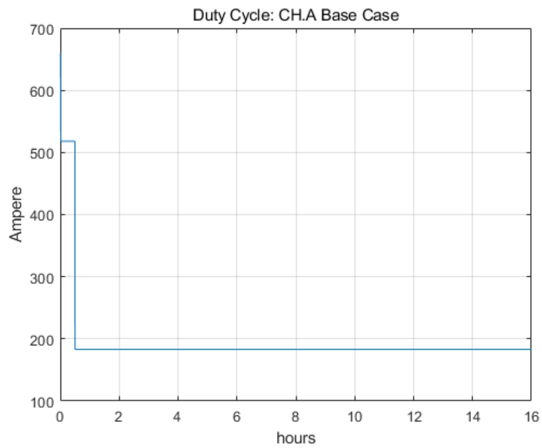

Fig. 2. Base Case Duty Cycle.

2.3 Alternative Case 1

Alternative Case 1 shed loads after 2 hours from SBO and continue discharge for 16 hours. Fig. 3. shows duty cycle of the Alternative Case 1.

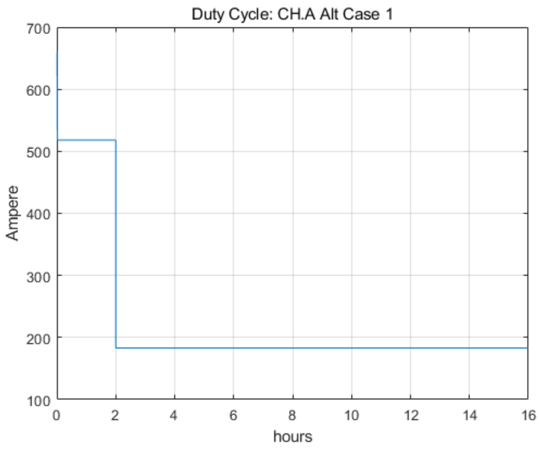

Fig. 3. Alternative Case 1 Duty Cycle.

2.4 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. Fig. 4. shows duty cycle of the Alternative Case 2.

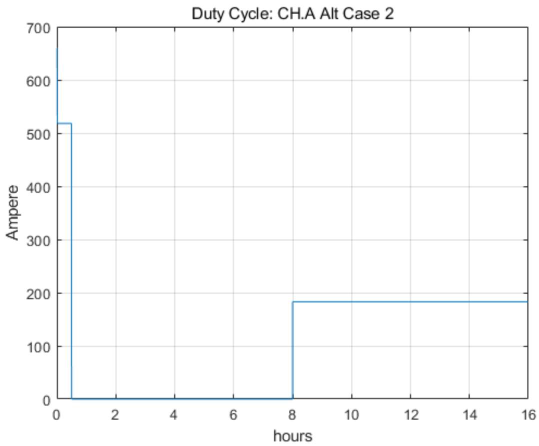

Fig. 4. Alternative Case 2 Duty Cycle.

2.5 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. Fig. 5. shows duty cycle of the Alternative Case 3.

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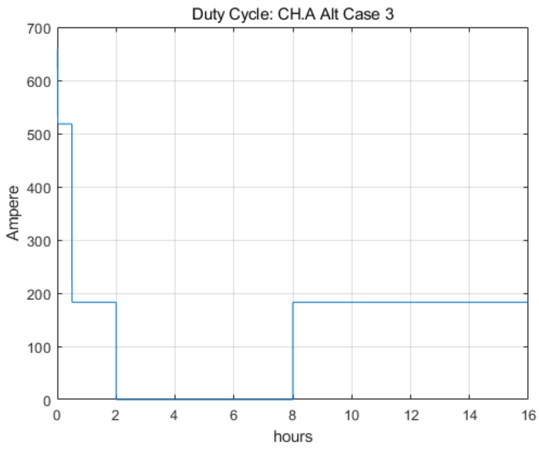

Fig. 5. Alternative Case 3 Duty Cycle.

2.6 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. Fig. 6. shows duty cycle of the Alternative Case 4.

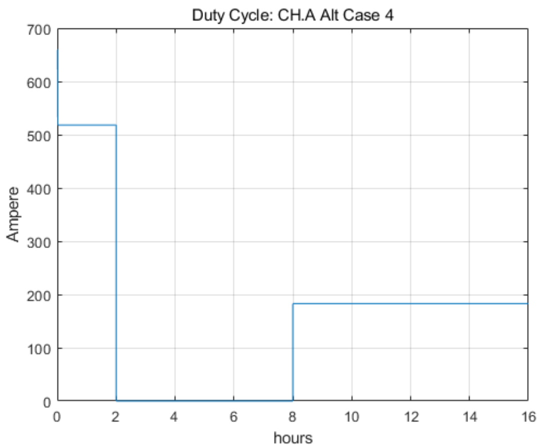

Fig. 6. Alternative Case 4 Duty Cycle.

3. Study Result

Calculation results are summarized in Table 1. 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.

Table I: Calculation Result

	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

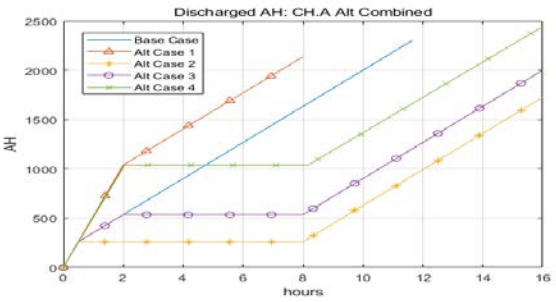

Fig. 7. Discharged AH of all cases

Fig. 7. presents discharged AH of all cases. End points of each line show maximum discharge time without exceeding installed battery capacity.

Alt Case 1 showed shorter back-up time although it has relatively longer duration 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. 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.

4. Conclusions

In this study, Alternatives were set up considering delays 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.

ACKNOWLEDGMENT

This work was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety using the financial resource granted by the Nuclear Safety and Security Commission of the Republic of Korea. (No. 1805006)

REFERENCES

[1] S. B. Park et al., Evaluation of Battery Coping Time for Extended Station Blackout, KINS/RR-1799, 2018.
[2] IEEE, Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications, IEEE Std. 485, 2010.
[3] Design Provisions for Withstanding Station Blackout at Nuclear Power Plants, IAEA TECDOC-1770, 2015.
[4] W. Gunther et al., Testing to Evaluate Extended Battery Operation in Nuclear Power Plants, NUREG/CR-7188, 2014.
[5] KHNP, Class 1E battery Calculation in ELAP, RE-E-001, 2018.