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AN ANALYSIS OF LOSS OF OFFSITE POWER WITH A PWR AT SHUTDOWN*

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In many Probabilistic Risk Assessments (PRAs), loss of offsite power (LOOP) when a nuclear power plant is operating was found to be a significant contributor to core damage. The purpose of this study is to provide an analysis of a loss of offsite power event that occurs while a PWR is shut down. The importance of such an analysis was recognized as part of a study[1] to evaluate the core damage frequency due to a loss of decay heat removal capability during an outage.

When a PWR is in a shutdown condition, there are relatively few Technical Specification requirements on the operability of safety systems. In fact, some safety systems are intentionally disabled, e.g., the safety injection system and nonoperating charging pumps. A comparison of the component maintenance unavailabilities estimated in NSAC-84[2] with those estimated in Zion Probabilistic Safety Study[3] (ZPSS) shows that maintenance unavailability of hardware tends to be higher during an outage. For example, 4 kV essential buses may be under maintenance during an outage. Another problem when the reactor is shut down is that the Reactor Coolant System (RCS) may be partially drained and the steam generators may be unavailable. If a station blackout occurs when the reactor is at power, the turbine-driven auxiliary feedwater pump should be available to remove the decay heat. This may not be the case

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if the reactor is in shutdown. On the other hand, more time is available for operators to restore power or initiate other systems that may be used to mitigate the event. NSAC-84[2] assessed (for Zion) that the frequency of station blackout with the plant at shutdown is 1.29×10^{-4} per year and the frequency of core damage due to LOOP is 2.3×10^{-7} per year. NSAC-84 does not provide a description of any ac power recovery model that may have been used. In this paper, an ac power recovery model is discussed.

To determine the time available for operator actions given that a LOOP occurs during shutdown and the decay heat removal (DHR) capability is lost, a simple thermal model has been developed.[1] It assumes that the RCS is drained to the hotleg midplane, and determines the core uncovery time as a function of the time (after shutdown) when the decay heat removal function is interrupted. The results of the model are plotted in Figure 1. Also plotted in Figure 1 are ac power recovery probabilities taken from two sources. The four dots in Figure 1 are probabilities taken from NUREG/CR-4550[4] for Zion. The circles plotted in Figure 1 are the results of NUREG-1032[5] for the probability that offsite power is not restored by the specified times. They are calculated using Figure A.1 of NUREG-1032. It can be seen that the ac nonrecovery probability used in NUREG/CR-4550 for Zion is not very different from the offsite power nonrecovery probability given in the generic data base. For calculational convenience, a staircase function was fitted through the dots as shown in Figure 1. For example, if DHR capability is lost in the interval 105 hours to 280 hours after shutdown as a result of a LOOP, the probability that ac power is not restored before core uncovery occurs is 0.07.

It is estimated[2] that the frequency of refueling outages is 0.747 per year and that the reactor coolant system is drained to the hotleg midplane at 167 hours after shutdown. It is also estimated[1] that the plant stays in the drained condition for two to three weeks to perform steam generator eddy current testing and other tests or maintenance that require draining of the RCS. Therefore, the core damage frequency due to loss of offsite power during a drained condition can be calculated as follows:

frequency (LOOP occurs when RCS is drained in a refueling outage)
*Prob. (no decay heat removal and no makeup|LOOP)
*Prob. (ac power not recovered before core uncovery)

$$= 0.747/\text{year} * 8.3*10^{-6}/\text{hour} *[(280 \text{ hour} - 167 \text{ hour}) * 0.07 + (587 \text{ hour} - 280 \text{ hour}) * 0.04] * 1.1*10^{-2}$$

$$= 1.38*10^{-6} \text{ per year}$$

where $8.3*10^{-6}$/hour is the rate that LOOP occurs, and $1.1*10^{-2}$ is the unavailability of Residual Heat Removal (RHR), safety injection, and charging systems.

Similar calculations have been done for other phases of refueling and maintenance outages. A total core damage frequency due to LOOP while the plant is in shutdown has been calculated to be $5.9*10^{-6}$ per year. This is approximately twice the core damage frequency[4] calculated for LOOP when the plant is at power.

References

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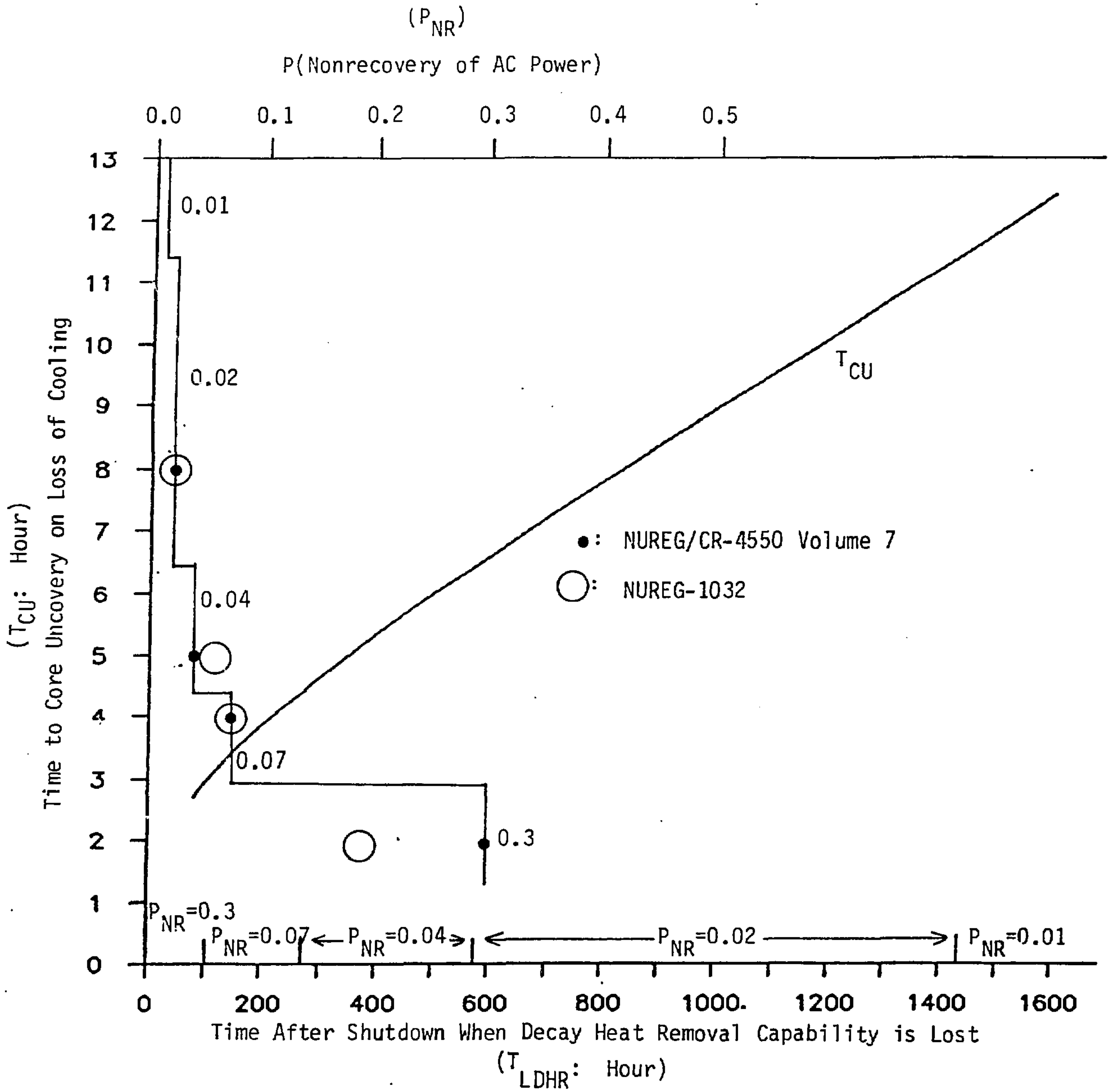

Figure 1 Model of ac power recovery.