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Relative Cost vs. Reliability Improvement of Nuclear-Power-Plant Onsite AC Power Systems

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Abstract

Emergency onsite ac power systems at nuclear power plants are a major concern in plant risk assessments because of the relatively large frequency of loss of offsite power and the dependence of most other safety systems on ac power. Detailed reviews of onsite ac power system designs and reviews of experience with diesel generators at U. S. nuclear power plants form the basis of system reliability analyses that show significant improvements in reliability can be obtained at moderate cost for some plants. Onsite ac power system modifications analyzed include procedural modifications, minor equipment modifications and major equipment additions. Relative costs of various modifications are compared with associated system reliability improvements.

Introduction

This paper presents selected results of a reliability study of nuclear power plant emergency ac power systems conducted under a contract with the Nuclear Regulatory Commission as part of their effort to resolve the issue of station blackout. Station blackout is defined as complete loss of ac power to the emergency buses at a plant. This definition is extended to include situations where insufficient ac power for core cooling requirements is available to multiple reactor unit plants. Almost all U. S. nuclear power plants use diesel generators as emergency ac power sources. In most cases, if offsite power is unavailable, one diesel generator provides sufficient power for one unit, but not for two units. Only ac power systems utilizing diesel generators are considered in this paper.

This paper focuses specifically on median point estimates of system failure probability for onsite ac power system design configurations that are most prevalent at operating U. S. nuclear power plants. Design and procedure modifications that affect the systems' reliabilities are postulated, and the reliability improvement associated with each modification to each system configuration is estimated. Consideration is given to relative costs associated with the various modifications.

The analysis of station blackout consists of assessing the frequency of loss of offsite power (Ref. 1), determining the probability the onsite ac power system fails to supply sufficient ac power for the duration of the loss of offsite power (Ref. 2), and analyzing the plant response to station blackout using probabilistic risk assessment methods (Ref. 3). The onsite ac power system analysis utilized diesel generator experience data for the five-year period from 1976 through 1980. Detailed design reviews of selected plants and plant visits provided information pertinent to onsite ac power system configurations.

The onsite ac power system analysis did not focus on a simultaneous loss of coolant accident (LOCA) and loss of offsite power as an initiating event. Rather, it focused on loss of offsite power and plant transients induced by the loss of offsite power as the initiating event based on consideration of the relative frequencies of these two possible initiating events. The analysis focused directly on the most significant contributions to system failure probability. A number of nuclear power plant risk assessments have identified station blackout as a major contributor to risk (Refs. 4,5). These same risk assessments show failures of emergency power distribution system equipment have a negligible contribution to the system failure probability; the failure probability is dominated by the probability ac power is not available to the emergency buses.

Reliability Analysis Procedure

The onsite ac power system analysis used fault trees to model the ac power system failure logic. Figure 1 presents a fault tree for a typical single-unit plant with two redundant emergency ac power divisions. This fault tree reflects the dependence of diesel generators on service water for cooling, and on dc power for logic and control functions. The emergency ac distribution system at a plant depends on dc power from its associated dc division for breaker control power as well.

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