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Reliability of the Emergency AC Power System at Nuclear Power Plants*

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At nuclear power plants there are many safety systems that are dependent on ac power. At commercial nuclear power plants in the United States this ac power is normally supplied by the utility's power grid (offsite source), and if this power source is unavailable the ac power is supplied at most plants by diesel generators located onsite at the nuclear power plant. Because of the importance of ac power and because of experienced failures, the NRC has identified the loss of onsite and offsite ac power-station blackout - as an unresolved safety issue. This unresolved safety issue was divided by NRC into three tasks: (1) reliability of offsite ac power supplies; (2) reliability of onsite ac power supplies; and (3) reliability of ac independent systems. This paper contains an evaluation of the onsite ac power system reliability.

The approach to determine the onsite system reliability is to gather from the operating nuclear plants detailed data that have not been available to the NRC, to select typical but detailed design features, and to combine the two to determine ac power system reliability for different designs. Fault trees were constructed from the specific designs, and the categorized data will be used to calculate a spectrum of the expected frequency of station blackout. Fig. 1 is a fault tree of a typical unit with two diesel generators.

The detailed data needed for this task were not available in public files. The only data available were in the Licensee Event Report (LER) files of NRC, but these data were not complete enough for the reliability evaluation for this

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task. Therefore, a data questionnaire was prepared and sent to most nuclear plant licensees to obtain extensive data on the history of their diesel generators for the years 1976-80. The types of diesel generator data that were collected are the following: failure description, number of test starts and starts for the loss of offsite power or safety injection actuation signal, number of hours of preventive or unscheduled maintenance repair time for failures, and modifications or improvements that have been made since initial criticality. The sources of these data are Licensee Event Reports, responses to the NRC questions in the NUREG-0737, and the questionnaire sent out as part of this task. These sources combined contain detailed data on diesel generator history of operation from 1976-80.

The large loss of coolant accident coincident with a loss of offsite power is considered to be of low enough probability that it is not included in the reliability evaluation. A loss of offsite power coincident with a small coolant leak is an event that is included. Based on this type of event, a definition of failure of the diesel generator is given.

Definition of diesel generator failure: a diesel generator test or actual demand during which the diesel generator did not or would not for a loss of offsite power or safety injection actuation signal supply sufficient ac power without repair to the emergency bus.

The failures are subdivided into primary (intrinsic) and secondary (extrinsic) failures. There is also another category called autostart failure. These are the events that would be failures except they are restored to operation quickly by an operator. There were 410 failures out of 1388 events reported to NRC. The failure data are also categorized by subsystem failure. From this a pie-chart is drawn, see Fig. 2, that shows the percentage contribution to failure by each subsystem. From this pie-chart it can be seen there is no single significant contributor to failure. Lowering the industry average number of failures significantly will require improvements in many different diesel generator subsystems. The failure start, repair, and test and maintenance data will be presented in histograms that show the distribution of the different parameters. Also shown will be trends of failure rates for old and new nuclear plants. The failure and start data will be used to calculate the probability of failure on demand. A histogram will be made that shows the distribution of failure on demand throughout the industry.

Another category is that of common cause failure. The common cause failure events will be categorized by design, operation, or maintenance; they will also be categorized by events that are plant specific or generic and can occur at any plant. The results of some of the calculations of the probability of common cause failures will be presented.

Detailed design information was collected for 18 plants. The information consists of a single line diagram from the switchyard to the plant dc buses, and it also contains descriptions of the diesel generator subsystems. These designs are representative of the spectrum of emergency ac power system designs. The number of plants with each type of design is shown in Table 1 tabulated. These designs have been used to develop fault trees for the reliability analysis. A simple fault tree based on the most prevalent design - two diesels per unit - will be included.

For each design studied there will be a probability of station blackout. An industry average probability for the loss of offsite power will be used. A low and high probability of station blackout will be presented. The more important contributors to the probability of station blackout will be identified.

The results of this task will improve significantly the understanding of the reliability of emergency ac power systems because of the detailed data that were collected, the extensive effort to categorize the data, and the detailed design review. The data have not only been treated generically, but they have also been used for plant specific calculations where they apply. Complete results for this task are not available yet, but the task is scheduled to be complete by the end of March. This paper is a companion paper with that of A. K. Kolaczkowski of Sandia National Laboratory.

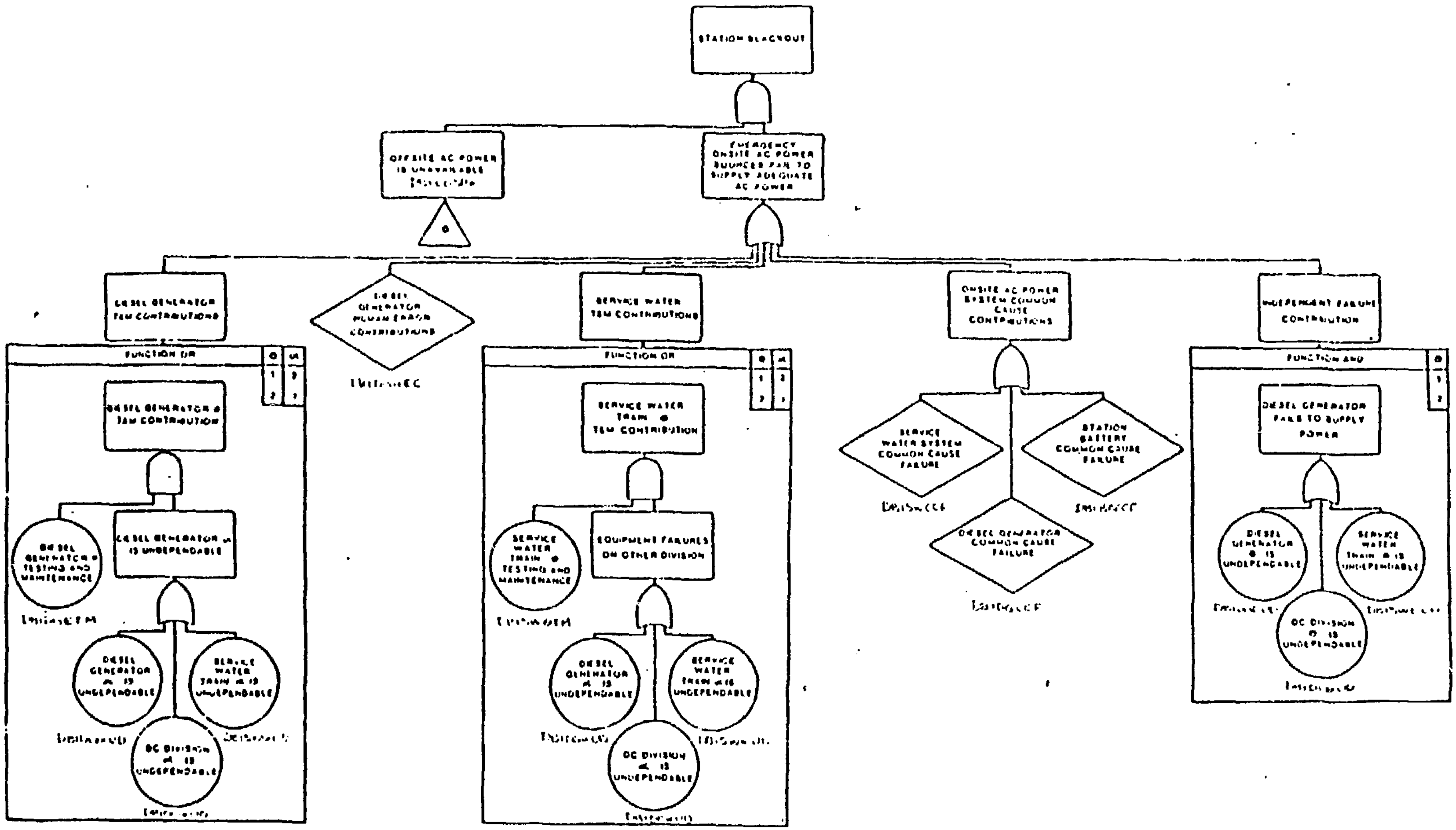

Figure 1. Fault Tree

Figure 2. SUBSYSTEM FAILURE PERCENTAGES

1976 - 1980

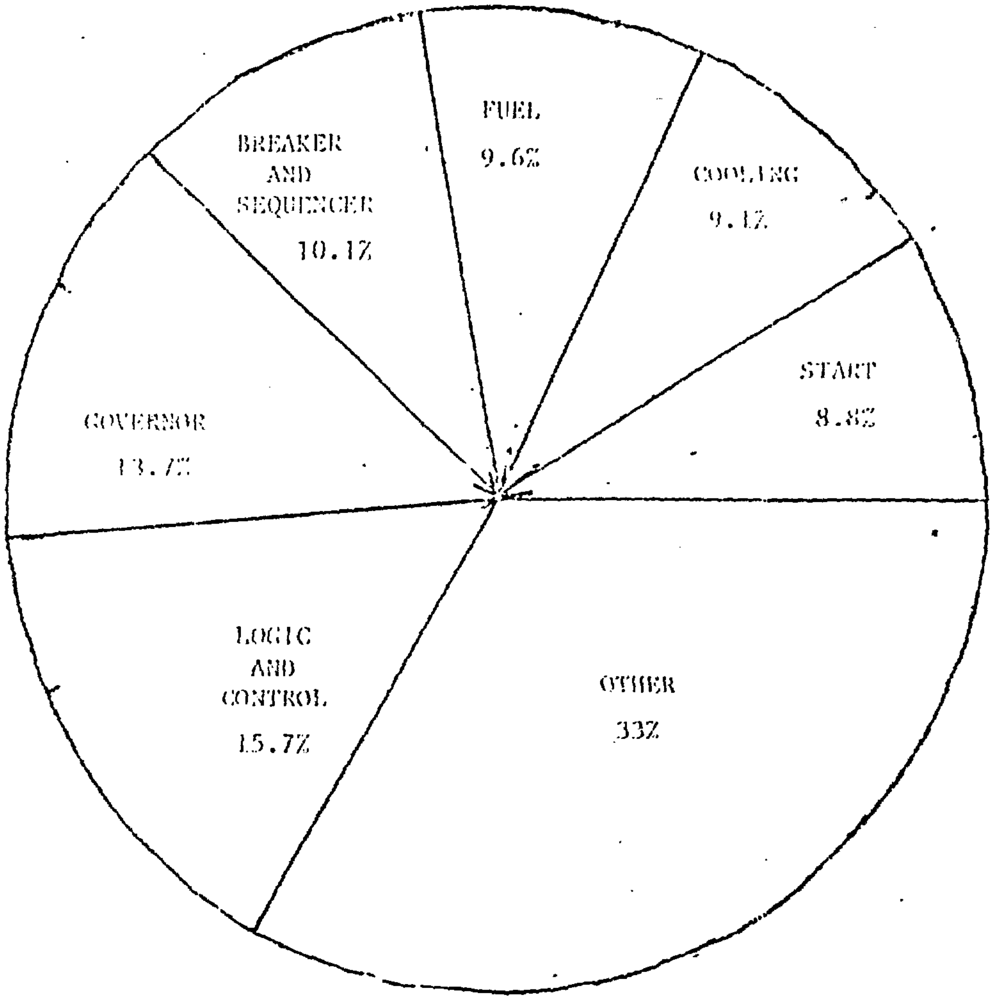

Table 1. DIESEL GENERATOR DESIGN CONFIGURATIONS

DG Success Criterion for Initiating Events other than Large LOCA	Number of Units	Number of Plants
I. DGs Dedicated to One Unit		
A. 1/1	3	3
B. 1/2	30	26
C. 1/3	6	5
D. 2/4	1	1
II. DGs Shared Between Two Units		
A. 1/2	6	3
B. 2/3	8	4
C. 2/4	6	3
D. 2/5	6	3
III. DGs Shared Between Three Units		
A. 3/8	3	1