Reliability Study Update

Emergency Diesel Generator

1997–2003

This report presents a performance evaluation of the emergency diesel generators (EDGs) at U.S. commercial power plants. The evaluation is based on the operating experience from 1997 through 2003. This is the latest update to NUREG/CR 5500 Volume 8. The data for the initial EDG study were obtained from LERs and Special Reports for plants reporting under Regulatory Guide 1.108 for 1987 through 1993. Plants have not been reporting these Special Reports to NRC since RG 1.108 was canceled. Therefore, the EDG results used in this update were obtained from the Equipment Performance and Information Exchange (EPIX) database using the Reliability and Availability Database System (RADS) software for 1997 through 2003.

This report calculates two basic models for the EDGs. The first model, start mission, models the period when the EDG has achieved rated speed and/or voltage (FTS) and the load and run model (FTLR). The load and run demand includes the loading of the EDG and closing of the output circuit breaker, as well as the first hour of operation. The EDG run mission (FTR) is for seven hours to make a total of 8-hours of operation.

1 LATEST VALUES AND TRENDS

1.1 Industry-Wide Unavailability and Unreliability

The industry-wide unavailability and unreliability of the EDGs have been estimated from operating experience. A failure to start (FTS) unavailability and a 7-hour mission unreliability were evaluated, see Table 1. The estimates are based on failures that occurred during unplanned demands, and cyclic and quarterly surveillance tests.

Table 1. Industry-wide values.

Model		Lower (5%)	Mean	Upper (95%)
No Recovery	Failure-to-Start (Unavailability)	9.82E-03	1.63E-02	2.40E-02
	7-hour Mission (Unreliability)	1.40E-02	2.26E-02	3.29E-02
With Recovery	Failure-to-Start (Unavailability)	9.30E-03	1.39E-02	1.93E-02
	7-hour Mission (Unreliability)	1.12E-02	1.71E-02	2.40E-02

1.2 Fail to Start Model Results

A highly statistically significant[1] decreasing trend is shown for the industry estimates of EDG Unavailability (FTS), without Recovery, on a per fiscal year basis. No statistically significant trend is shown for the Unavailability with Recovery case. Figure 1 shows the trend in the FTS model, Unavailability without Recovery. Table 2 shows the data points for Figure 1. Figure 2 shows the trend in the FTS model, Unavailability with Recovery. Table 3 shows the data points for Figure 2.

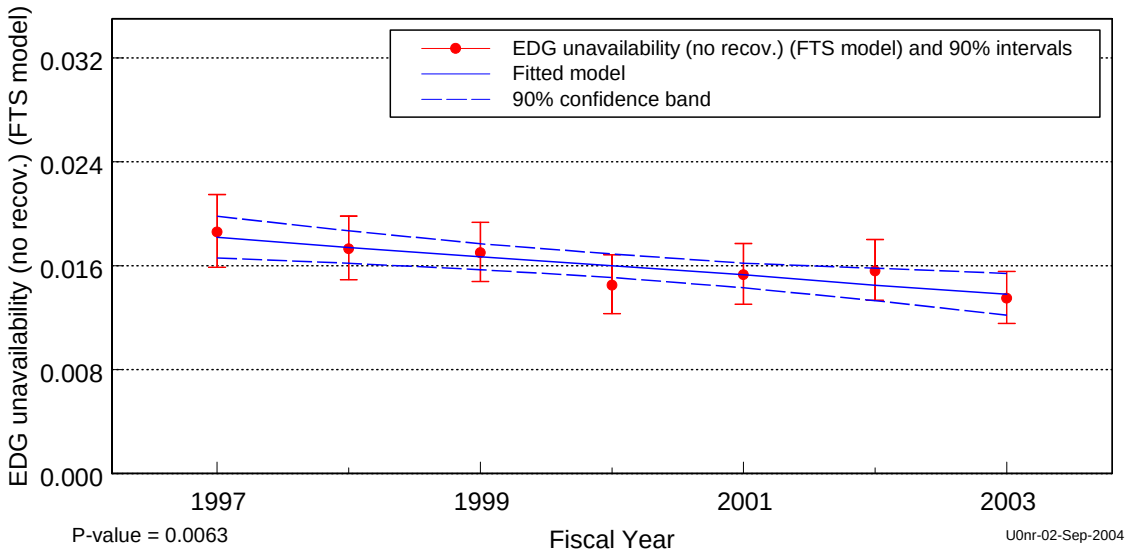

Figure 1. Trend of EDGs unavailability (FTS model, no recovery), as a function of fiscal year.

[1] Statistically significant is defined in terms of the 'p-value.' A p-value is a probability indicating whether to accept or reject the null hypothesis that there is no trend in the data. P-values of less than or equal to 0.05 indicate that we are 95% confident that there is a trend in the data (reject the null hypothesis of no trend.) By convention, we use the "Michelin Guide" scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

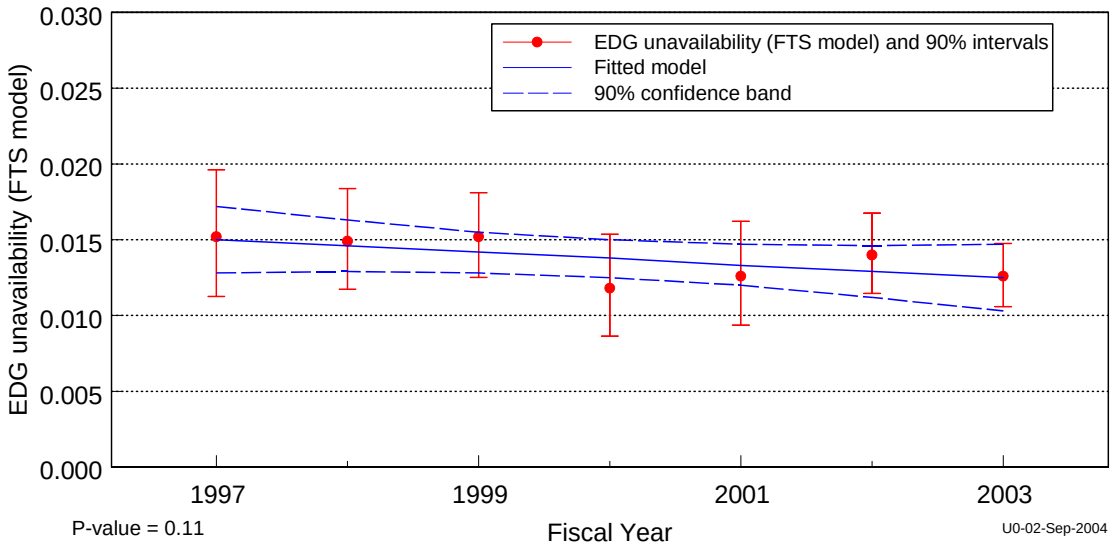

Figure 2. Trend of EDGs unavailability (FTS model, with recovery), as a function of fiscal year.

1.3 Fail to Operate for 7-Hour Model

No statistically significant trend within the industry estimates of EDGs Unreliability (7-hour mission), with or without Recovery, on a per fiscal year basis was identified. Figure 3 displays the trend by fiscal year of the EDGs unreliability calculated from the 1997–2003 experience without recovery. Table 4 shows the data points for Figure 3. Figure 4 shows the trend in the 7-hour mission model unreliability with recovery. Table 5 shows the data points for Figure 4.

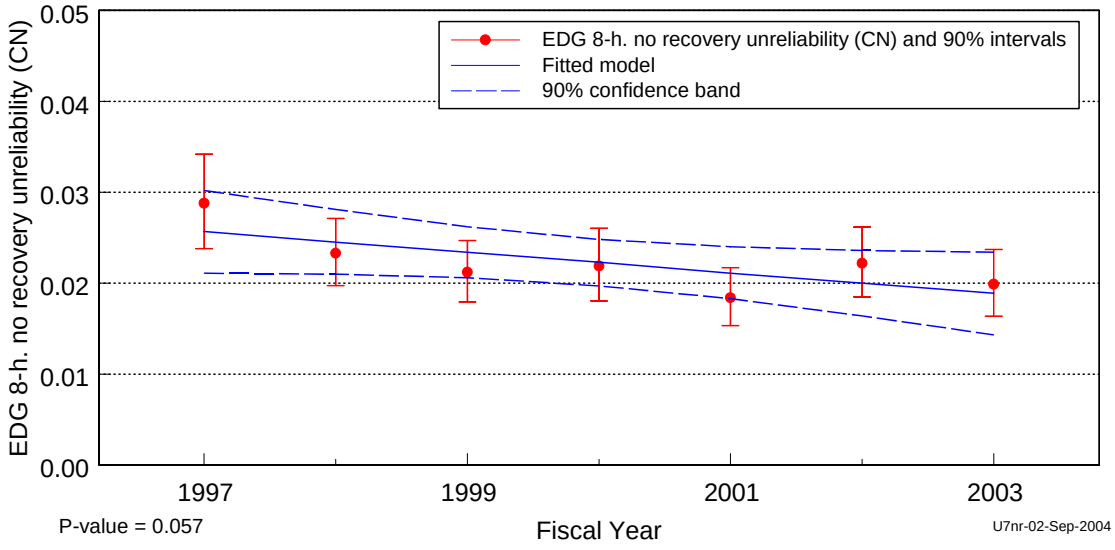

Figure 3. Trend of EDGs unreliability (7-hour model, no recovery), as a function of fiscal year.

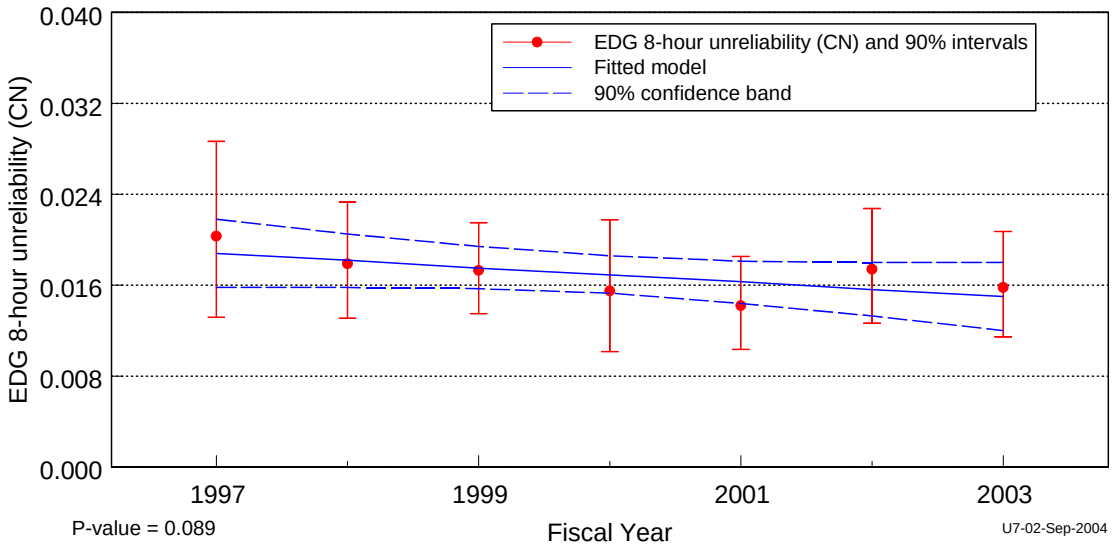

Figure 4. Trend of EDGs unreliability (7-hour model, with recovery), as a function of fiscal year.

2 DATA TABLES

2.1 Data Tables for Unreliability and Unavailability Trends

Table 2. Plot data table for EDGs unavailability, FTS model, no recovery, Figure 1.

	Plot Trend Error Bar Points			Regression Curve Data Points		
FY	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1997	1.58E-02	1.86E-02	2.14E-02	1.66E-02	1.82E-02	1.98E-02
1998	1.50E-02	1.73E-02	1.98E-02	1.62E-02	1.74E-02	1.87E-02
1999	1.48E-02	1.70E-02	1.94E-02	1.57E-02	1.67E-02	1.77E-02
2000	1.23E-02	1.45E-02	1.68E-02	1.51E-02	1.60E-02	1.69E-02
2001	1.30E-02	1.53E-02	1.77E-02	1.43E-02	1.53E-02	1.62E-02
2002	1.33E-02	1.56E-02	1.80E-02	1.33E-02	1.45E-02	1.58E-02
2003	1.16E-02	1.35E-02	1.56E-02	1.22E-02	1.38E-02	1.54E-02

Table 3. Plot data table for EDGs unavailability, FTS model, with recovery, Figure 2.

	Plot Trend Error Bar Points			Regression Curve Data Points		
FY	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1997	1.12E-02	1.52E-02	1.96E-02	1.28E-02	1.50E-02	1.72E-02
1998	1.17E-02	1.49E-02	1.84E-02	1.29E-02	1.46E-02	1.63E-02
1999	1.25E-02	1.52E-02	1.81E-02	1.28E-02	1.42E-02	1.55E-02
2000	8.62E-03	1.18E-02	1.54E-02	1.25E-02	1.38E-02	1.50E-02
2001	9.37E-03	1.26E-02	1.62E-02	1.20E-02	1.33E-02	1.47E-02
2002	1.15E-02	1.40E-02	1.68E-02	1.12E-02	1.29E-02	1.46E-02
2003	1.06E-02	1.26E-02	1.48E-02	1.03E-02	1.25E-02	1.47E-02

Table 4. Plot data table for EDGs unreliability, 7-hour mission, no recovery, Figure 3.

	Plot Trend Error Bar Points			Regression Curve Data Points		
FY	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1997	2.38E-02	2.88E-02	3.42E-02	2.11E-02	2.57E-02	3.02E-02
1998	1.98E-02	2.33E-02	2.72E-02	2.10E-02	2.45E-02	2.81E-02
1999	1.80E-02	2.12E-02	2.47E-02	2.06E-02	2.34E-02	2.62E-02
2000	1.81E-02	2.19E-02	2.60E-02	1.97E-02	2.23E-02	2.48E-02
2001	1.53E-02	1.84E-02	2.17E-02	1.83E-02	2.11E-02	2.40E-02
2002	1.85E-02	2.22E-02	2.62E-02	1.64E-02	2.00E-02	2.36E-02
2003	1.64E-02	1.99E-02	2.37E-02	1.43E-02	1.89E-02	2.34E-02

Table 5. Plot data table for EDGs unreliability, 7-hour mission, with recovery, Figure 4.

	Plot Trend Error Bar Points			Regression Curve Data Points		
FY	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1997	1.32E-02	2.03E-02	2.87E-02	1.58E-02	1.88E-02	2.18E-02
1998	1.31E-02	1.79E-02	2.33E-02	1.58E-02	1.82E-02	2.05E-02
1999	1.35E-02	1.73E-02	2.15E-02	1.57E-02	1.75E-02	1.94E-02
2000	1.02E-02	1.55E-02	2.18E-02	1.53E-02	1.69E-02	1.86E-02
2001	1.03E-02	1.42E-02	1.85E-02	1.44E-02	1.63E-02	1.81E-02
2002	1.26E-02	1.74E-02	2.27E-02	1.33E-02	1.56E-02	1.80E-02
2003	1.15E-02	1.58E-02	2.08E-02	1.20E-02	1.50E-02	1.80E-02