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Characteristics Of Nuclear Power Plant Performance

’05 Probabilistic Safety Analysis (PSA)

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Abstract – *When analyzing U.S. commercial nuclear power plant performance in terms of selected initiating event frequencies and component unreliability, the data often appear to suggest two groups of performers – nominal and degraded. Given this observation, a limited review of the data was performed to investigate whether degraded performance typically is momentary or sustained. For example, do plants that exhibited degraded performance for a certain initiating event over one period also appear in the degraded performance category over the next period? The data review included a relatively simplistic review for two initiating events and two components followed by a more detailed analysis of one of the initiating events. The limited data review indicates that for the two relatively frequent initiating event categories and two important component types, the plant incursions into the degraded category are typically momentary (lasting one to several years) with subsequent returns to the nominal category. However, some interesting exceptions exist, and these need to be studied in more detail.*

I. INTRODUCTION

Two valuable databases containing performance information for U.S. commercial nuclear power plants are the initiating events database maintained by the U.S. Nuclear Regulatory Commission[1] (NRC) and the Equipment Performance and Information Exchange (EPIX) database maintained by The Institute of Nuclear Power Operations (INPO).[2] NRC uses these two databases to develop industry average initiating event frequencies and component unreliability estimates for its Standardized Plant Analysis Risk (SPAR) models[3] covering the 103 operating commercial nuclear power plants in the U.S.

In the past, these SPAR models contained selected plant specific component unreliability estimates, based on results presented in the system study analyses documented in the NUREG/CR-5500 series.[4] (These studies typically used data over approximately the period 1987 – 1995, and plant specific component unreliability estimates were generated if the statistical analyses indicated significant differences between plants.) However, data that are more recent indicated that the plants with the worst performance during the 1987 – 1995 period often were nominal performers in more recent years. In addition, overall industry performance for components has improved considerably since the late 1980s and early 1990s.[5] Therefore, to help decide whether the SPAR models should contain industry average performance or plant specific performance estimates, a limited data review was performed to determine whether plant excursions into the degraded category were momentary (lasting only a short period such as one to three years) or sustained (lasting more than three years).

II. OVERVIEW OF UPDATED INDUSTRY AVERAGE DATABASE FOR SPAR MODELS

The NRC SPAR models require inputs such as initiating event frequencies and component unreliability estimates. These inputs were recently updated using the initiating events database and the EPIX database. Trend analyses indicate that industry performance for both types of events has improved considerably since the 1980s and early 1990s. Therefore, only recent data, typically over the period 1998 – 2002, were used to generate what are termed the "Year 2000" industry average estimates. (The performance estimates are centered about the year 2000.)

When analyzing the plant specific and component specific data over this recent period, often the data appeared to indicate that two groups existed – nominal performance and degraded performance. A logical question was then whether the plants or components in the degraded performance category remained there over time or returned to the nominal

performance category. If degraded performance typically returns to nominal performance within a short time, then industry average values are appropriate for the NRC SPAR models. (For specific analyses using these models, some plant specific values may be appropriate.) This issue was studied by using a simplistic comparison approach followed by a more detailed look at a single initiating event. Both approaches are discussed in the following sections.

III. SIMPLISTIC COMPARISON OF "WORST 10" PLANTS FOR TWO PERIODS

As a first step in investigating whether plants exhibited cyclic performance, two different initiating events and two components were compared for the periods 1997 – 1999 and 2001 – 2003. These recent periods generally represent the current industry average performance. In addition, the EPIX database started in 1997.

For initiating events, the general transient (TRANS in SPAR) and loss of condenser heat sink (LOCHS) were studied. In SPAR, these two initiating events subdivide into pressurized water reactor (PWR) and boiling water reactor (BWR) categories, each with their own frequency. To compare plant performance for the PWR TRANS initiating event, plant specific numbers of events and corresponding reactor critical years (rcry's) were tabulated for 1997 – 1999 and 2001 – 2003. Plant specific Bayesian updates, using the industry mean frequency and a constrained noninformative prior,[6] indicate plant specific performance. Plants ordered from highest frequency (posterior mean from the Bayesian update) to lowest indicate the "worst 10" in terms of frequency. Comparison of "worst 10" lists from both periods identified any plants in both lists, indicating sustained degraded performance.

This same process was also followed for the BWR TRANS, PWR LOCHS, and BWR LOCHS initiating events. Results in Table 1 indicate that for the PWR TRANS initiating event, only two of 10 plants in the "worst 10" list for 1997 – 1999 were in the same list for 2001 – 2003. In addition, for PWR LOCHS, only one of eight plants was in both lists. (During 1997 – 1999, only eight PWRs experienced at least one LOCHS, so the "worst 10" list actually contains only eight plants.) These two results clearly indicate for the PWR cases that most plant excursions into the degraded category were momentary (lasting only several years at most).

However, for BWR TRANS and BWR LOCHS, the results are not as clear. For BWR TRANS, five of 10 plants in the "worst 10" list for 1997 – 1999 were also in the same list for 2001 – 2003. In addition, for BWR LOCHS, four of 10 were in both lists. Therefore, for these two cases there appear to be cases where plant excursions into the degraded performance category were not momentary but were sustained (lasting more than three years).

TABLE 1. Initiating Event Comparison between Periods

Initiating Event	Plants in "Worst 10" List for both 1997 – 1999 and 2001 – 2003
PWR TRANS	2 of 10 in first list were in second list
PWR LOCHS	1 of 8 in first list were in second list (note a)
BWR TRANS	5 of 10 in first list were in second list
BWR LOCHS	4 of 10 in first list were in second list

Note a – Only 8 plants experienced a LOCHS during 1997 – 1999.

The results summarized in Table 1 were also reviewed for correlations between different types of initiating events. For example, if a plant exhibited degraded performance for PWR TRANS, did it also exhibit degraded performance for PWR LOCHS? Results of this comparison are summarized in Table 2. For the period 1997 – 1999, there appears to be almost no correlation between TRANS and LOCHS performance at a plant. However, the results for 2001 – 2003 appear to indicate a strong correlation. At present, the reasons for this difference in results for 1997 – 1999 versus 2001 – 2003 are not known.

In addition to the simplistic review of plant performance for the TRANS and LOCHS initiating events, a similar review was performed for two important component types – emergency diesel generators (EDGs) and standby turbine-driven pumps (TDPs). In the updated SPAR component database, both of these components have three distinct failure modes – failure to start (FTS), failure to run for the first hour of operation (FTR<1H), and failure to run after the first hour of operation (FTR>1H). (For the EDGs, the FTR<1H failure mode is actually termed failure to load and run for one hour, or FTLR, to indicate that for EDGs this failure mode includes the loading of the EDG onto the emergency electrical bus and sequencing of loads onto the bus.)

TABLE 2. Initiating Event Correlation

Initiating Events	1997 – 1999 "Worst 10" Plant Lists	2001 – 2003 "Worst 10" Plant Lists
PWR TRANS and LOCHS	1 of 8 in LOCHS list was in the TRANS list	5 of 8 in LOCHS list were in the TRANS list
BWR TRANS and LOCHS	1 of 10 in LOCHS list was in the TRANS list	6 of 10 in LOCHS list were in the TRANS list

The analysis of component performance data is similar to that for initiating events. Data from EPIX for each component and failure mode, collected for 1997 – 1999 and for 2001 – 2003, provide the information for developing plant specific estimates. Bayesian updates for each failure mode used the industry average mean and a constrained noninformative prior. Results for each plant assemble into a combined unreliability using the equation

$$UR_{combined} = FTS + (FTR<1H)(1h) + (FTR>1H)(7h).$$

An eight-hour total mission time is approximately the average run time observed for unplanned demands on EDGs.

Combined unreliability results (posterior mean from the Bayesian updates), ordered from highest (worst performance) to lowest, identify the "worst 10" lists of plants. Results for both components, summarized in Table 3, indicate that only one plant that was in the "worst 10" list for 1997 – 1999 was in the same list for 2001 – 2003. Therefore, most plant excursions into the degraded category for these two component types appear to be momentary (lasting only several years at most).

The results summarized in Table 3 were also reviewed for correlations between different types of components. For example, if a plant exhibited degraded performance for EDGs, did it also exhibit degraded performance for standby TDPs? Results of this comparison, summarized in Table 4, indicate very little correlation between EDG and standby TDP performance at a plant for the period 1997 – 1999. However, the results for 2001 – 2003 appear to indicate a correlation. At present, the reasons for this difference in results for 1997 – 1999 versus 2001 – 2003 are not known.

TABLE 3. Component Unreliability Comparison Results between Periods

Component	Plants in "Worst 10" List for both 1997 – 1999 and 2001 – 2003
EDGs	1 of 10 in first list was in second list
Standby TDPs	1 of 10 in first list was in second list

TABLE 4. Component Unreliability Correlation

Component	1997 – 1999 "Worst 10" Plant Lists	2001 – 2003 "Worst 10" Plant Lists
EDGs and Standby TDPs	1 of 10 in EDG list was in the standby TDP list	4 of 10 in EDG list were in the standby TDP list

IV. DETAILED STUDY OF PWR TRANS

The simplistic comparisons summarized in Section III suffer from several deficiencies. First, three-year periods of data were used for all of the initiating events and components studies. Ideally, the data period analyzed should depend upon the expected number of events per year, given industry average performance. Second, the "worst 10" lists obtained may contain plants operating within the nominal performance bounds and therefore not exhibiting degraded performance.

In order to address these deficiencies, a more detailed review of the PWR TRANS initiating event data was performed. (Similar types of detailed analyses could be performed for the other initiating events and component types.) Because this event is relatively frequent, the data aggregation period was chosen to be yearly, rather than every three years (or a rolling three-year average). The initiating event database contains information for 1988 through the present. For this analysis, the period 1988 – 2002 was used. Information collected for each plant and each year included the number of TRANS occurrences and the corresponding rcry. Assuming a Poisson process for TRANS, the probability of observing the number of TRANS occurrences given the industry average frequency and plant specific rcry provides information on whether the plant is performing nominally.

Results in Table 5 highlight (grey background) cases where the probability is less than 0.05. (The 0.05 probability is used in statistical analyses to support decisions, but other cut off criteria could also be used, depending upon the purposes of the

analysis.) In addition, Table 5 summarizes the yearly total number of plants with probabilities less than 0.05, along with the industry average frequency.

Several observations can be made concerning the results presented in Table 5. First, there are 64 plant and year entries that have probabilities less than 0.05, out of a total of 1014 entries (not counting the ones in which the plant did not operate during the year, indicated by N/A). Out of the 1014 entries, even if all of them represent operation in the nominal performance category, one would expect approximately (1014)(0.05) = 50.7 ≈ 51 entries in the less than 0.05 probability of occurrence category. (Each year, approximately three to four plants might lie in this category even if all plants were operating nominally.) Therefore, entries with probabilities less than 0.05 should not necessarily be characterized as exhibiting degraded performance.

For this example, plants that lie in the degraded operation category might be those that have probabilities less than 0.01. There are 16 such entries. Most of these entries occurred during the period 1988 – 1994, with only three identified for 1995 – 2002.

Concerning the momentary versus sustained performance issue, 54 of the 64 entries with probabilities less than 0.05 have no adjacent entries with probabilities less than 0.05. For these cases, the plant was in this state for only one year and then returned to performance that had a probability greater than 0.05 of being observed given nominal (industry average) performance. The remaining 10 entries involve five cases where the plant remained in the less than 0.05 category for two adjacent years. Finally, of the 16 events probably lying in the degraded performance category (those with probabilities less than 0.01), only two had an adjacent year with a probability less than 0.05. Therefore, plant excursions into the less than 0.05 probability of occurrence category or even the degraded performance category lasted at most two years for the PWR TRANS initiating event.

V. COMPARISON WITH REACTOR OVERSIGHT PROCESS PERFORMANCE INDICATOR THRESHOLD

Selected PWR TRANS results for 2000 – 2002 in Table 5 can be compared with the Reactor Oversight Process (ROP) Unplanned Scrams performance indicator. That indicator uses a threshold of greater than three events per 7000 reactor critical hours (evaluated over the past four quarters) as indicating a plant excursion into degraded (WHITE) performance. Results in Table 5 indicate four PWR TRANS events within a year are required to result in a probability of occurrence of less than 0.01. (The six events during 2000 – 2002 with probabilities less than 0.05 but greater than 0.01 all involve three events within the year in question. In 1999, one entry had a probability of occurrence of less than 0.01, and in that case, the plant experienced four events during the year.)

A detailed comparison of ROP Unplanned Scram results with the PWR TRANS results at the plant level was not performed because the definitions of events used in each program are not identical. For example, the ROP Unplanned Scram category includes all unplanned scrams, while the SPAR model definition for PWR TRANS does not include initiating events covered separately within the risk model (e.g., LOCHS, loss of offsite power, and others).

VI. SUMMARY AND CONCLUSIONS

A limited review of plant performance was performed, covering two types of initiating events and two component types. The primary purpose of the review was to determine whether excursions into what might be termed degraded performance are momentary (lasting one to several years) or sustained. Results appear to indicate that in general such excursions into degraded performance are momentary. However, this study was limited and one possible exception was noted. (BWR initiating events covered in the study indicated some sustained degraded performance.)

A secondary purpose of the study was to identify cases whether degraded performance in one initiating event was correlated to degraded performance in other initiating events (or between component types).

TABLE 5. Probability of Observing Plant Data (Number of Occurrences) for PWR TRANS over 1988 – 2002

	Probability of Observing 1-Year Total Number of Events (PWR TRANS)														
PWR	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.244	0.085	0.165	0.290	0.196	0.339	0.275	0.232	0.182	0.370	0.120	0.489	0.343	0.104	0.328
2	0.250	0.251	0.115	0.314	0.229	0.199	0.315	0.217	0.352	0.401	0.475	0.521	0.587	0.340	0.334
3	0.215	0.082	0.236	0.209	0.287	0.364	0.192	0.303	0.367	0.092	0.240	0.123	0.339	0.322	0.526
4	0.165	0.264	0.287	0.272	0.184	0.353	0.357	0.352	0.360	0.158	0.811	0.524	0.508	0.342	0.538
5	0.293	0.268	0.046	0.360	0.192	0.328	0.368	0.366	0.402	0.432	0.521	0.458	0.487	0.533	0.516
6	0.000	0.213	0.283	0.254	0.083	0.348	0.179	0.226	0.385	0.422	0.359	0.128	0.350	0.339	0.538
7	0.204	0.166	0.179	0.192	0.272	0.253	0.367	0.285	0.157	0.462	0.513	0.350	0.486	0.514	0.105
8	0.107	0.101	0.291	0.279	0.320	0.246	0.354	0.261	0.390	0.367	0.481	0.479	0.134	0.337	0.540
9	0.047	0.260	0.184	0.272	0.145	0.233	0.271	0.098	0.368	0.370	0.475	0.498	0.355	0.324	0.322
10	0.202	0.557	0.586	0.332	0.316	0.262	0.047	0.123	0.468	0.382	0.510	0.354	0.341	0.515	0.276
11	0.239	0.573	N/A	0.346	0.073	0.363	0.086	0.093	0.366	0.444	0.458	0.512	0.475	0.573	0.516
12	0.080	0.210	0.172	0.119	0.232	0.350	0.272	0.260	0.464	0.405	0.475	0.487	0.344	0.342	0.535
13	0.002	0.270	0.314	0.331	0.270	0.345	0.018	0.223	0.346	0.159	0.489	0.348	0.346	0.323	0.516
14	N/A	N/A	0.001	0.007	0.140	0.036	0.229	0.101	0.174	0.368	0.481	0.489	0.469	0.551	0.577
15	N/A	N/A	N/A	N/A	N/A	0.061	0.010	0.248	0.050	0.364	0.361	0.350	0.503	0.342	0.329
16	0.224	0.270	0.146	0.302	0.353	0.185	0.394	0.367	0.203	0.586	N/A	N/A	0.972	0.329	0.327
17	0.380	0.252	0.109	0.269	0.485	0.261	0.137	0.042	0.368	0.340	N/A	N/A	0.671	0.326	0.321
18	0.186	0.250	0.213	0.058	0.332	0.342	0.333	0.219	0.279	N/A	0.130	0.501	0.477	0.552	0.341
19	0.355	0.173	0.239	0.200	0.271	0.242	0.317	0.219	0.379	0.392	0.026	0.472	0.516	0.514	0.920
20	0.038	0.226	0.263	0.059	0.315	0.315	0.367	0.225	0.198	0.415	0.450	0.123	0.112	0.514	0.307
21	0.268	0.219	0.127	0.181	0.138	0.343	0.206	0.338	0.368	0.057	0.489	0.350	0.478	0.540	0.340
22	0.187	0.209	0.217	0.017	0.318	0.193	0.322	0.229	0.322	0.460	0.333	0.358	0.327	0.553	0.112
23	0.044	0.120	0.165	0.270	0.001	0.351	0.230	0.225	0.393	0.370	0.495	0.520	0.355	0.083	0.559
24	0.098	0.201	0.211	0.160	0.103	0.238	0.354	0.095	0.405	0.394	0.510	0.496	0.492	0.556	0.543
25	0.242	0.249	0.013	0.177	0.266	0.340	0.367	0.349	0.360	0.401	0.443	0.116	0.347	0.514	0.547
26	0.206	0.113	0.114	0.320	0.126	0.186	0.340	0.227	0.367	0.038	0.353	0.035	0.348	0.618	0.025
27	0.220	0.293	0.199	0.199	0.178	0.279	0.271	0.188	0.019	0.009	0.774	0.347	0.906	0.339	0.547
28	0.218	0.306	0.253	0.266	0.221	0.778	N/A	0.038	0.427	0.016	0.357	0.347	0.133	0.538	0.340
29	0.241	0.216	0.119	0.189	0.302	0.248	0.314	0.234	0.147	0.573	0.349	0.455	0.343	0.314	0.525
30	0.127	0.225	0.234	0.341	0.256	0.368	0.367	0.113	0.357	0.353	0.353	0.505	0.355	0.555	0.332
31	0.251	0.200	0.318	0.176	0.012	0.092	0.317	0.241	0.363	0.125	0.360	0.350	0.343	0.516	0.330
32	0.084	0.141	0.268	0.363	0.481	0.013	0.339	0.556	0.853	N/A	N/A	0.300	0.023	0.112	0.089
33	0.071	0.269	0.017	0.344	0.123	0.361	0.357	0.289	0.757	N/A	0.000	0.515	0.469	0.567	0.329
34	0.160	0.141	0.215	0.331	0.192	0.288	0.301	0.333	0.191	0.401	0.467	0.455	0.347	0.544	0.516
35	0.044	0.106	0.279	0.276	0.262	0.243	0.356	0.359	0.366	0.370	0.354	0.351	0.134	0.309	0.636
36	0.044	0.262	0.250	0.262	0.153	0.253	0.333	0.268	0.365	0.595	0.507	0.344	0.525	0.528	0.553
37	0.206	0.209	0.125	0.136	0.192	0.342	0.366	0.342	0.500	0.360	0.339	0.004	0.469	0.546	0.556
38	0.252	0.257	0.210	0.130	0.051	0.315	0.187	0.352	0.362	0.348	0.341	0.458	0.345	0.614	0.341
39	0.169	0.275	0.343	0.133	0.015	0.404	0.417	0.316	0.397	0.409	0.345	0.532	0.513	0.785	0.335
40	0.095	0.302	0.364	0.265	0.241	0.354	0.274	0.227	0.367	0.368	0.352	0.348	0.469	0.556	0.329
41	0.264	0.109	0.336	0.254	0.174	0.366	0.167	0.355	0.368	0.365	0.443	0.349	0.343	0.331	0.546
42	0.051	0.265	0.266	0.121	0.202	0.254	0.164	0.264	0.365	0.366	0.481	0.455	0.504	0.323	0.516
43	0.061	0.081	0.128	0.266	0.309	0.221	0.297	0.350	0.345	0.804	0.596	0.525	0.127	0.558	0.547
44	0.176	0.224	0.117	0.305	0.179	0.332	0.310	0.357	0.364	0.806	0.538	0.515	0.103	0.112	0.548
45	0.061	0.166	0.248	0.295	0.210	0.318	0.337	0.219	0.385	0.359	0.132	0.501	0.480	0.082	0.335
46	0.062	0.216	0.104	0.136	0.225	0.241	0.354	0.263	0.365	0.439	0.332	0.457	0.344	0.541	0.542
47	0.186	0.111	0.257	0.320	0.262	0.304	0.191	0.355	0.185	0.368	0.127	0.486	0.355	0.547	0.547
48	0.213	0.184	0.147	0.333	0.280	0.080	0.003	0.630	N/A	N/A	0.549	0.120	0.031	0.087	0.330
49	0.005	0.132	0.337	0.316	0.084	0.367	0.173	0.279	N/A	0.701	0.502	0.511	0.507	0.342	0.559
50	0.052	0.311	0.253	0.231	0.270	0.246	0.271	0.318	0.354	0.491	0.483	0.510	0.508	0.522	0.094
51	0.255	0.246	0.175	0.286	0.331	0.355	0.271	0.284	0.339	0.477	0.461	0.347	0.469	0.670	0.519
52	N/A	0.059	0.050	0.015	0.141	0.053	0.362	0.352	0.365	0.359	0.346	0.503	0.329	0.328	0.541
53	0.008	0.237	0.268	0.208	0.267	0.024	0.164	0.025	0.366	0.425	0.354	0.455	0.101	0.544	0.516
54	0.029	0.095	0.270	0.278	0.143	0.300	0.434	0.042	0.166	0.401	0.145	0.478	0.123	0.514	0.095
55	0.076	0.269	0.000	0.116	0.346	0.871	0.194	0.104	0.344	0.367	0.443	0.029	0.330	0.534	0.523
56	N/A	0.000	0.060	0.013	0.177	0.009	0.358	0.242	0.335	0.013	0.356	0.352	0.469	0.020	0.013
57	0.220	0.183	0.330	0.141	0.277	0.102	0.024	0.212	0.156	0.358	0.358	0.123	0.469	0.331	0.539
58	0.044	0.269	0.290	0.136	0.131	0.231	0.367	0.364	0.203	0.412	0.472	0.357	0.498	0.332	0.517
59	0.105	0.058	0.131	0.191	0.271	0.344	0.403	0.228	0.358	0.163	0.447	0.122	0.560	0.574	0.095
60	0.235	0.346	0.289	0.136	0.260	0.260	0.368	0.353	0.321	0.361	0.026	0.455	0.349	0.568	0.516
61	0.160	0.073	0.197	0.239	0.144	0.028	0.292	0.029	0.059	0.168	0.443	0.345	0.499	0.535	0.331
62	0.216	0.167	0.137	0.265	0.271	0.336	0.287	0.252	0.321	0.432	0.443	0.494	0.469	0.571	0.516
63	0.146	0.270	0.248	0.307	0.252	0.195	0.364	0.348	0.202	0.159	0.127	0.358	0.495	0.544	0.516
64	0.298	0.350	0.169	0.722	0.317	0.245	0.206	0.224	0.368	0.366	0.443	0.479	0.347	0.340	0.530
65	0.003	0.082	0.089	0.194	0.277	0.249	0.363	0.334	0.172	0.439	0.443	0.482	0.346	0.342	0.565
66	N/A	0.003	0.093	0.174	0.262	0.251	0.218	0.347	0.368	0.370	0.027	0.349	0.469	0.539	0.320
67	0.207	0.206	0.267	0.017	0.189	0.263	0.365	0.282	0.367	0.492	0.354	0.105	0.510	0.342	0.540
68	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.049	0.042	0.360	0.504	0.495	0.023	0.331
69	0.113	0.236	0.087	0.238	0.266	0.257	0.322	0.335	0.367	0.151	0.443	0.349	0.508	0.514	0.326
Totals (<0.05 entries)	12	2	6	5	3	5	5	5	3	5	4	3	2	2	2
Yearly Rate (1/rcry)	3.12	2.84	2.43	2.00	2.00	1.69	1.31	1.52	1.13	1.00	0.82	0.79	0.76	0.67	0.66

Results from that comparison, again from a limited review, were puzzling. For the period 1997 – 1999, no correlation was noted. However, for the period 2001 – 2003, a potentially significant correlation was observed.

Finally, a more detailed review of PWR TRANS initiating event data on a yearly basis revealed several insights. First, plant excursions into the degraded category typically lasted only one year. Only several cases were noted where the degraded performance lasted two years, and in no cases did the degraded performance last more than two years. Second, statistical analyses based on current industry average frequencies for PWR TRANS indicated that more than three events within a year were required to clearly categorize the plant performance as degraded (lying outside the nominal industry average range). This agrees with the ROP Unplanned Scrams performance indicator, in which more than three events within 7000 critical hours are required to place a plant in the WHITE category.

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VII. REFERENCES

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