RELIABILITY OF AC POWER AT GGNS
An Interim Assessment

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1.0 INTRODUCTION

1.1 Summary of Purpose and Scope

The purpose of this document is to provide preliminary(1) reliability calculations which can be used to evaluate the acceptability of AC power system performance at GGNS. This includes an evaluation of the system design as proposed in the GGNS FSAR, along with estimates of reliability under a variety of interim configurations and conditions. Specifically, the following information is supplied.

1. Preliminary estimates of the reliability of offsite power sources. Included are estimates of the frequency of losing all offsite power supplies to the site simultaneously (LOSP), the conditional probability of recovering at least one power source to the site as a function of time, the conditional probability that a LOSP is tornado caused, and the sensitivity of the frequency of a LOSP to the relative likelihood of tornadoes at various times of the year.

2. Reliability of AC power at the site for Division 1 and 2 loads. This includes the frequency of losing offsite sources and the unavailability of onsite AC power from diesel generators (D/G).

3. Reliability of a backup gas turbine generator (GTG) emergency AC power system to start up and assume ESF bus loads for the duration of a LOSP given failures of the D/Gs. This includes an assessment of inherent unit reliabilities as well as sources of human error.

4. Sensitivities of AC power reliability to variations in expected D/G reliability and to modified operating scenarios (i.e., assuming that one D/G is out for inspection).

5. The comparative reliability of AC power for an integrated system consisting of D/Gs and a backup system of GTGs to provide highly reliable power to key ESF loads.

6. The comparative reliability of AC power at GGNS to that at other plants based on information from reliability review.

7. The potential importance of AC power reliability as an impact on public safety at GGNS (as measured by core melt frequency), along with a discussion of the potential effects of modified AC power reliability on risk to the public.

1.2 Conclusions of Study

Conclusions which can be drawn from the analysis in this document are as follows:

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(1) A more detailed reliability evaluation of the AC power system at GGNS is currently being performed by MP&L.

1.0 INTRODUCTION

1. The GGNS AC power system is a reliable source of power for Division 1 and 2 ESF loads. Based on the estimated frequency of complete offsite LOSP (all three sources), median time to recovery of at least one offsite source, and reasonable reliability of the TDI D/Gs to start and bear load for the duration of the LOSP, unavailability of AC power is expected to occur with a frequentcy of approximately 5x10-4/R-yr using generic industry data. This estimate does not include availability of the GTG AC power system. This frequency compares well with NRC estimates of the frequency of AC power loss for a cross section of nuclear power plants and power system design configurations, using plant data and plant specific D/G experience where possible. Current GGNS starting experience with the TDI D/Gs indicates a higher starting reliability than that used in the calculations. In addition, a conservative estimate of the time to recovery of at least one offsite source was used. Therefore the predicted AC power system reliability is a conservative estimate of expected system performance.

2. The GTGs represent a reliable additional source of emergency power for the AC power system. For a system success criteria requiring at least 2 of 3 GTGs to start and bear load for the duration of the LOSP, system reliability is estimated to be approximately 96% using current industrial reliability experience with the particular GTG design used at GGNS. The GTGs do not reside inside an area protected from tornado damage. However, it is not expected that a single event such as a tornado could fail all offsite sources and the GTGs simultaneously, since anticipated paths of any tornados going through the site would be unlikely to intersect both the GTGs and the switchyard.

3. An enhanced AC power system with GTGs used as a backup for the existing TDI D/Gs provides substantial additional protection against a loss of AC power in the event of a LOSP. For postulated situations in which the AC power system is operating under additional constraints including a) higher anticipated failure rates for the TDI D/Gs during operation, or b) unavailability of one TDI D/G; addition of the GTGs decreases overall AC power system unreliability to a level of 2.7x10-5/R-yr and 1.5x10-4/R-yr respectively, which exceeds the reliability of the original system configuration. For these preliminary estimates it was assumed that a loss of all AC power to Division 1 and 2 ESF buses for 25 minutes was acceptable, based on station blackout studies.

4. Removal of 1 D/G from service for up to three months during the portion of the year when tornadic action is at a minimum in Mississippi, further assures the reliability of AC power at the GGNS site, provided that the GTGs are available as a source of power to the ESF bus.

5. Reliability of the AC power system at GGNS compares favorably with AC power reliability at other plants given that similar assumptions are used in the reliability assessment. Reliability of the AC power system, even with degraded D/G reliability, does not pose a significant contribution to public risk; especially when the GTGs are utilized as a backup power source.

1.3 Report Organization

Supporting technical arguments for these conclusions as provided in this document are organized in the following manner.

1. Section 2.0 evaluates an expected frequency for a LOSP at GGNS and estimates the time needed to recover at least one source of offsite power. Estimates are prepared using MP&L data..

2. Section 3.0 provides a preliminary reliability model which is used to evaluate AC power reliability in the event of a LOSP.

3. Section 4.0 provides a review of reliability information and a data base which is used to quantify AC power reliability. Section 4.0 also provides a sensitivity evaluation of AC power reliability under a variety of conditions and assumptions.

4. Section 5.0 provides a comparison of AC power reliability results for GGNS with those derived in other studies. In addition, a perspective on the contribution of AC power to public risk at GGNS is provided.

2.0 ESTIMATION OF LOSP FREQUENCY AND RECOVERY TIMES

Establishing a reasonable estimate of the likelihood of a complete loss of offsite power for the GGNS site is a key element of an analysis of the frequency of AC power loss. The RSSMAP for GGNS suggests a frequency of .2/R-yr for a complete loss of grid. The following arguments are given to illustrate that for the GGNS site, a lower LOSP frequency than that used in the RSSMAP can be supported based on historical experience for MP&L's grid.

The GGNS site has three incoming transmission lines, two 500 KV lines and a single 115 KV line. The possibilities for losing all three lines at the same time include:

- independent and simultaneous outage of all three lines
- loss of the grid due to an instability (such as that which occurred in the northeast U.S. in 1967)
- coupled loss of all power sources locally due to conditions such as adverse weather or a seismic occurrence.

Loss of all offsite power links to a plant as a result of a grid-related instability has never occurred on MP&L's grid or other grids in the local power pool. It is not considered a reasonable contribution to the frequency of LOSP.

Of the events which can cause a coupled loss of power, the tornadic events represent the principal vulnerability and their effects are evaluated herein. A review of transmission line outage data for the MP&L grid reveals that of the approximately half are tornado-induced events. All of the events which have caused outage of more than one major transmission line simultaneously are tornado-caused.

Using MP&L's transmission line outage experience and the assumption that failure rates are constant over time, estimates of LOSP frequency are produced along with measures of uncertainty.

2.1 Frequency of Total Grid Loss Assuming Independent Outages

From the Data Base in MP&L submittal AECM-84/0241, dated 4/18/84 there were:

- 39 outages in 500 KV lines in 12 years, and
- 8 outages in the 115 KV line which connects Natchez, Port Gibson, GGNS and Baxter-Wilson PS in 12 years.

For the 115 KV line this corresponds to P_3 = .727 outages per year. For the 500 KV lines,

- there are 520.3 total miles of 500 KV line in the system
- the outage rate per mile per year can be assumed to be constant, and
- the distances from GGNS to the two power sources which are in turn supplied by multiple feeders is 21.96 mi. and 43.53 mi. respectively.

Therefore the failure rate/500 KV mile - year is:

$$f_{500KV} = \frac{39}{520.3 \times 12} = .006 \text{ outages/mile - year}$$

The independent failure rate for each of the two segments connecting GGNS with other plants is:

$$P_1 = f_{500KV} \times 43.53 \text{ mi} = .272 \text{ outages/year}$$

$$P_2 = f_{500KV} \times 21.46 \text{ mi} = .134 \text{ outages/year}$$

The frequency of all three lines into GGNS failing due to independent failures can be approximated by:

$$P = P_1 \times P_2 \times P_3 \cdot C_{12} \cdot C_{13}$$

$$= .134 \times .272 \times .727 \times \left(\frac{400}{8760}\right)^2 = 5.5 \times 10^{-5}/\text{R-yr}$$

Where C_{12} and C_{13} represent the conditional "time at risk" when loss of additional lines would represent a threat. For the purposes of this study, the "time at risk" is essentially a conservative estimate of the time needed to fully restore a downed 500 KV line.

2.2 Frequency of Coupled Outages

GGNS has 3 independent powerline interties running in diverse paths from the plant to the rest of the grid. Reviewing the data base from the MP&L submittal, there have been no cases on the MP&L grid over the last 12 years in which 3 independent and diverse incoming lines have been lost to a plant. There are 3 plants in MP&L's grid with similar offsite power configurations, GGNS with 6 years, the Baxter-Wilson PS with 12 years and the Ray-Braswell PS with 12 years.

Using the information that no simultaneous failures of three incoming power lines to a plant have occurred in 30 plant years of observation, an exponential estimator technique can be applied by assuming 1 failure in the near future. Thus,

- a mean outage rate of 0.3/R-yr is produced

- a 90% confidence upper bound on the outage rate of .16 is produced.

As a second estimating technique, the data on 2 simultaneous line outages to a plant is used. There were 4 instances in the MP&L data base which 2 lines were out at the same time;

- 3 of these have occurred at GGNS since 1978

- 1 of these occurred at the Ray-Braswell Station.

Of the 3 GGNS instances 2 can be removed since

- they involved a 500 KV line which was placed out of service voluntarily because of the danger of high water, and

- the line has been moved and would no longer be threatened by high water.

There are therefore 2 valid outages of 2 incoming lines in 30 plant years or .067 outages/plant year.

A third line can be presumed to be lost, either as a result of the same event which caused the other two outages, or as a result of an independent failure occurring during this time.

For an independent failure of a third transmission line to occur, an estimate of the time at risk is required. For the failure which occurred at the Ray Braswell Station, the outage time for recovery of at least one more line was 388 hours. For the failure at GGNS, an estimate of outage time is more difficult to assess since the plant was under construction and incoming power was not needed. It is not anticipated that GGNS would be operated with two incoming lines unavailable, therefore, the limiting case at risk for at risk time is the approximately 72 hours needed to attain cold shutdown given that two incoming lines have been lost. Considering the worst exhibited reliability, that of the 115 KV line,

$$P_3 = .727 \text{ outages/year} = 8.3 \times 10^{-5} \text{ outages/hour}$$

Therefore the conditional probability of a third outage given that two lines are already out is .006.

To estimate the conditional likelihood that an third power source is failed from the same event which caused the first two failures, the two recorded cases can be reviewed.

For the Ray Braswell event, accounts are that the two incoming lines were downed by separate tornadoes which struck the switch yard. Thus a third line would not necessarily be damaged and the conditional probability of a third line failure is low. Conversely, for the GGNS event, a single tornado hit the switch yard. This implies that the third line could easily have been damaged, although the 115KV line was not damaged. The data suggests that there is not a clear basis, even qualitatively, for assessing a conditional likelihood of failure. Therefore, a value of .5 is used.

The frequency for a complete loss of grid for GGNS can be stated in equation form as

$$f_{LOSP} = f_I + f_C$$

where f_I is the occurrence frequency for three independent failure and f_C is the frequency of coupled failures. In turn

$$f_C = f_2 [P_{I3} + P_{C3}]$$

where f_2 is the occurrence frequency for a loss of two lines, P_{13} is the conditional probability of a third independent failure and P_{C3} is the coupled probability of a third failure as a result of the same event which caused the first two.

Using the estimates discussed above

$$f_{LOSP} = 5.5 \times 10^{-5} + .067 [.006 + .5] = .034$$

If the data on other plant sites were excluded from consideration leaving only GGNS specific events, only one failure since 1978 is counted. In this case $f_2 = .167$. Also, if it were assumed that the likelihood of a third failure given two failures is unity the LOSP frequency would become

$$f_{LOSP} = 5.5 \times 10^{-5} + .167 = .167$$

which is consistent with the frequency used in the NRC's RSSMAP of GGNS.

EPRI data (NP2301 Loss of Offsite Power at Nuclear Plants, Data and Analysis) illustrated in the accompanying Table 1 shows a wide variation in LOSP frequencies, principally due to site specific experiences. Arkansas Nuclear One (ANO) is the only site in SPP, and although ANO 1 & 2 have never lost offsite power, the low experience base of 7 years indicates using the EPRI approach a of no better than .15.

Table 1

EPRI LOSP FRQUENCY AND RECOVERY TIME ESTIMATES BY REGION

REGIONAL COUNCIL	LOSP FREQUENCY (EVENTS/SITE YEAR)	MEDIAN RECOVERY TIME (HRS:MIN)
NPCC	.153	:19
MAAC	.061	1:24*
ECAR	.338	1:11
SERC	.046	1:24*
MAIN	.076	1:23
MARCA	.204	:29
SPP	.149	----**
WSCC	.090	:06

* MAAC and SERC aggregate estimate

** No recovery time data for SPP sites

A summary of the estimates and uncertainty bounds which are produced using the existing MP&L grad data is shown in Table 2. Based on the size of the data sample for the MP&L grid a best estimate of

$$f_{LSOP} = .1/R\text{-}yr$$

is used in the reliability analysis in order to acknowledge the good grid experience, and to conservatively account for uncertainties in the data base.

2.3 Estimated Time to Recovery of Offsite Power Links

To estimate time of recovery of at least one offsite power link, two sources of data can be used:

- EPRI NP2301 data on recovery times, and
- Data specific to the MP&L system.

A summary of the EPRI data for regional outage data is shown in Table 1. Notably, the estimates of recovery time are short. The EPRI report noted, however, that recovery time for events caused by adverse weather conditions were much longer. On a national basis, an average of 7.2 hrs. for time to recovery was estimated.

For the MP&L grid the probability of losing single lines due to tornadoes is high and the probability that multiple lines failures are due to tornado effects is overwhelming. MP&L data on outage times for specific events includes data on 500 KV and 115 KV lines. Using both data sources and weighting the outage times by .67 and .33 respectively, an average recovery time of 68 hours.

Although this average includes the 115 KV line data it is highly skewed by the 500 KV data, since recovery times for the 115 KV line are more consistent with EPRI data.

It seems likely that the 115 KV line would be recovered first. A best estimate of mean recovery time is made by assessing the shortest single line recovery time which in this case is the 115 KV line.

On May 3, 1984 the 115 KV line was lost due to adverse weather. Recovery time for the May 3 incident is estimated to be less than 12 hours. Including the May 3 incident in the data base for recovery times produces an average recovery time of less than 2 hours. Based on

- MP&L data on recovery of the 115 KV lines, and

- EPRI estimates of recovery time for a LOSP

a conservative median recovery time of 12 hours to re-establish one incoming line to the plant is used.

Figure 1 illustrates a log-normal model for recovery, with a median recovery time of 12 hours and an error factor of 5. The assumption of a log-normal model is consistent with existing risk assessments, and is used to assess the conditional probability of not recovering at least a single incoming line for specific time periods following a LOSP.

2.4 Seasonal Affects on the Frequency of LOSP

The frequency of loss of offsite power at GGNS is dominated by failures as a result of tornadic activity. This activity is most pronounced in the early spring as shown in the accompanying Figure 2. Using data for Mississippi compiled over a 32 year period, a reduction in tornado and subsequent offsite power loss frequency of 45% can be established by restricting consideration to a 90-day window beginning on June 1.

TABLE 2 SUMMARY OF LOSP FREQUENCY DATA REVIEW

DATA SOURCE	FREQUENCY OF LOSP (1/R-yr)		
	MLE(Note 1) f	LB(Note 1) $f_{.05}$	UB(Note 1) $f_{.95}$
• RSSMAP For GGNS (Note 2)	.2	-	-
• EPRI Estimate For SPP (Note 3)	.15	.01	.45
Based on MP&L Experience (Note 4)			
a) 3 simultaneous failures only (Note 5)	.03	.002	.16
b) 2 simultaneous failures with conditional third failure (Note 6)	.034	.006	.11
c) GGNS only (Note 7)	.17	.009	.79
• MP&L Case b) with "Quiet Season Impact"	.019	.0005	.044

Note 1 the technique used for statistical estimation is that utilized in EPRI NP-2301. As such the time occurrences of a LOSP are assumed to be exponentially distributed, the maximum likelihood estimate (MLE) is M/T where M is the number of occurrences in T years, and the 90% confidence bounds are a = .025/2T and a = .95/2T (the a's are chi-square fractiles for .05 with 2m degrees of freedom and .95 with 2m + 2 degrees of freedom respectively). For no failures experienced, MLE = 1/T is used as a conservative estimate.

Note 2 a conservative estimate with no supporting analysis is used.

Note 3 EPRI data for the Southern Power Pool is used. At the time of the EPRI analysis there was only one site in the region (Arkansas Nuclear) with 7 years of operating experience and no recorded incidents.

Note 4 three plants in the MP&L grid have similar intertie designs (ie. 3 incoming lines and diverse incoming paths) GGNS with 6 years of experience, Baxter-Wilson PS with 12 years of experience and Ray-Braswell PS with 12 years of experience.

Note 5 no recorded cases of three failure simultaneously have occurred in 30 plant years observed experience.

Note 6 two recorded cases of two simultaneous failures have occurred in 30 plant year with the conditional probability of a third failure assessed as .51.

Note 7 only 6 years of observation at GGNS are used with single failure of two lines and the conditional probability of a third failure assessed as .51.

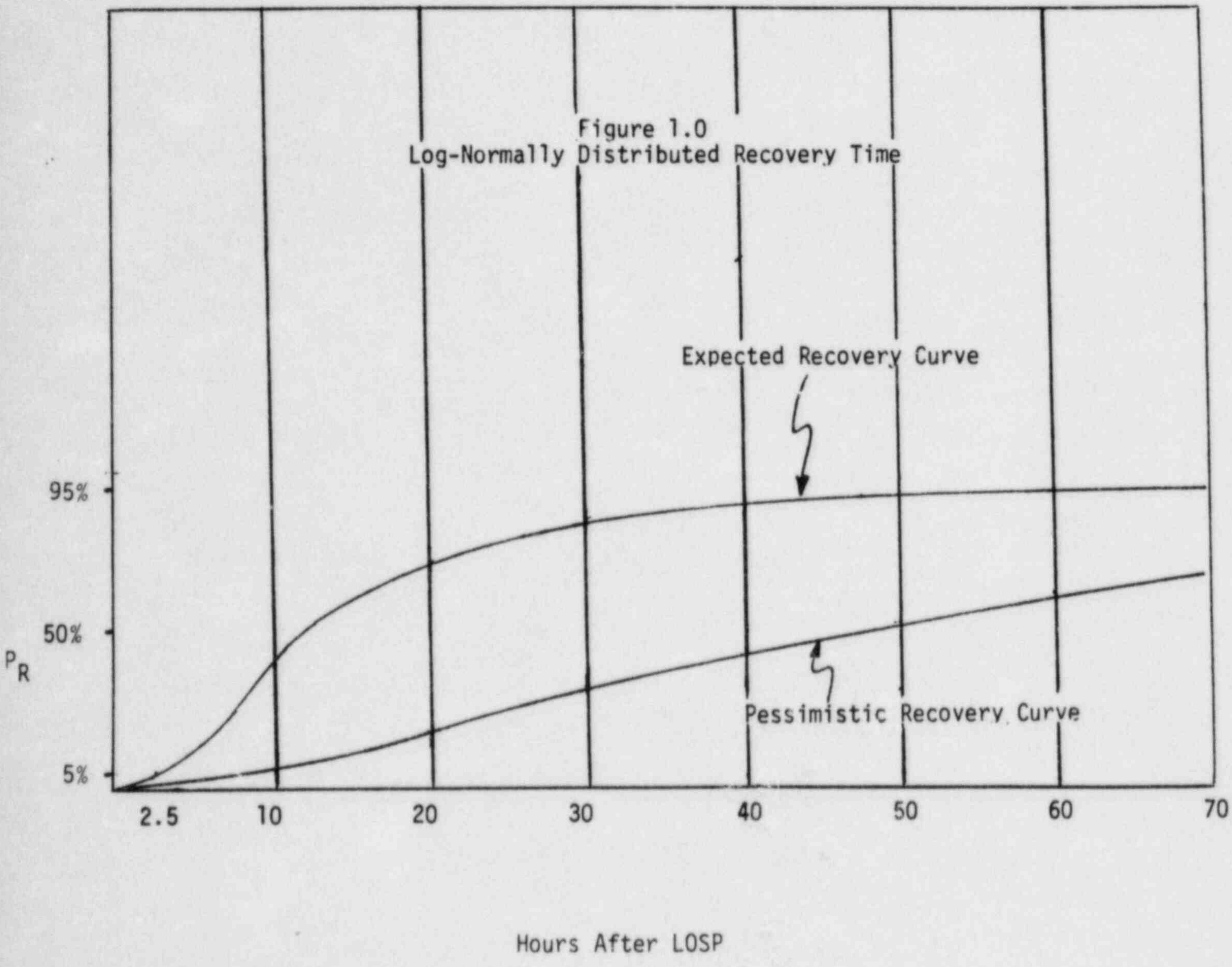

Figure 1.0
Log-Normally Distributed Recovery Time
Expected Recovery Curve
Pessimistic Recovery Curve
95%
50%
5%
P_R
2.5
10
20
30
40
50
60
70
Hours After LOSP

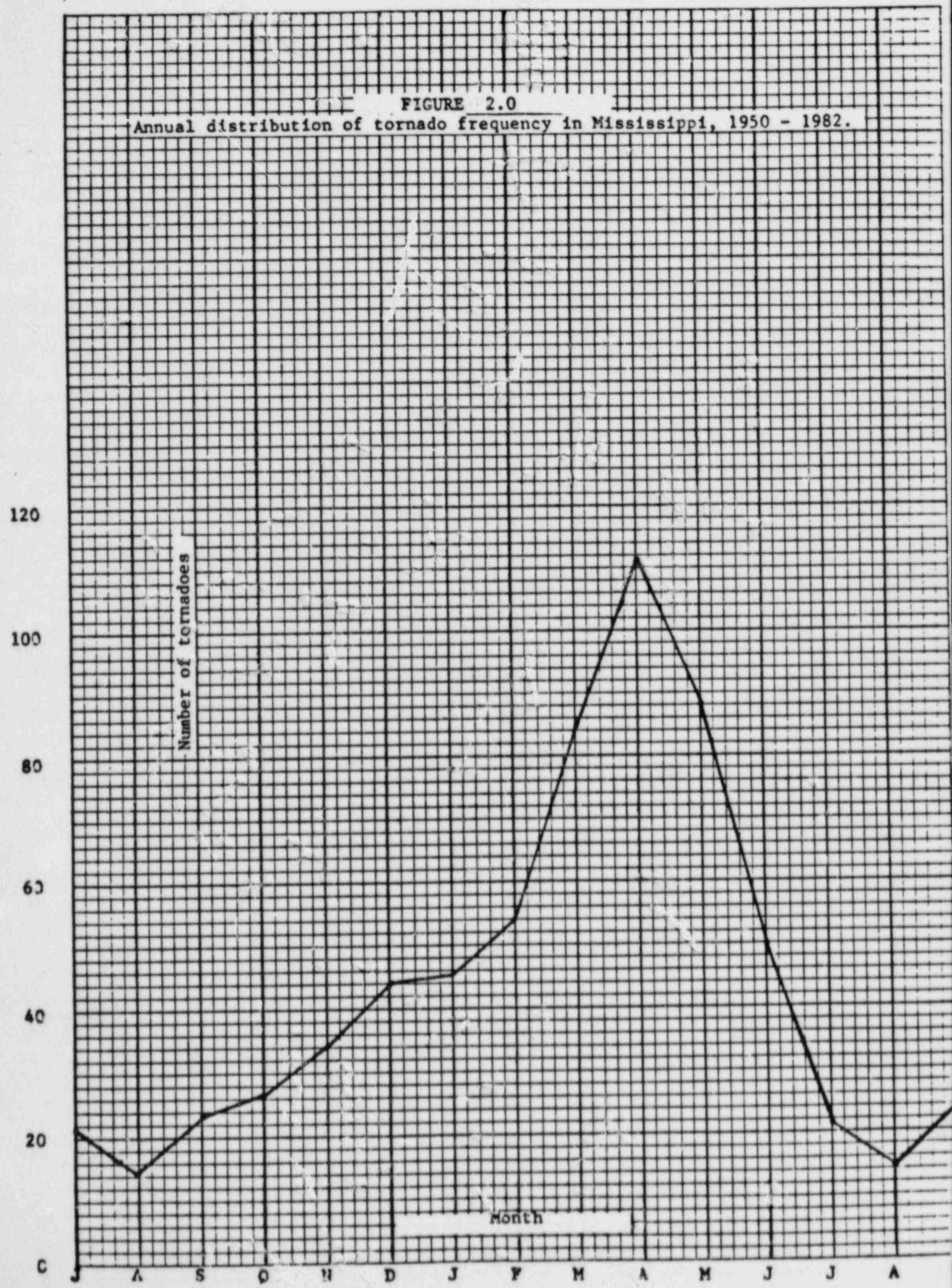

FIGURE 2.0

Annual distribution of tornado frequency in Mississippi, 1950 - 1982.

3.0 AC POWER SYSTEM RELIABILITY MODEL

The purpose of developing an AC power reliability model is to provide preliminary forecasts of AC reliability for the GGNS site and the logical relationship between major components and AC power system reliability at the site. Modeling of the AC power system is not intended to provide a detailed reliability evaluation and analysis of failure modes.

A fault logic model for AC power reliability is presented in Tables 3 and 4. Dependence models are used for both the diesel generators and the gas turbine generators to provide more realistic reliability estimates. For starting reliability of diesel generators there is experience indicating that failures of multiple units are not totally independent.

Failures of instrumentation and controls associated with supplying startup signals for the diesel generators are not modeled directly, since these are usually identified as relatively minor contributors to the unavailability of a single diesel generator. Likewise failure of support systems associated with cooling the diesel generators are not considered directly.

Gas turbines are modeled as being directly equivalent to at least one diesel generator in terms of being able to supply power to an ESF bus of choice. Since the design requirements for diesel generators include the ability to start and bear load in 10 seconds and the gas turbines are expected to be on line in approximately 22 minutes, the assumption of equivalency requires some explanation.

For the loss of offsite power initiator, loss of all AC power to Division 1 & 2 loads would not impair coolant makeup to the core, since the HPCS and its attendant diesel generator are still available. The major requirement for Division 1 and 2 loads given the occurrence of a LOSP, is associated with removal of decay heat. Therefore the gas turbine system starting time does not impair its usefulness for this purpose provided that the Division III HPCS D/G is operable. It should be noted that MP&L intends to continuously operate the GTGS under certain conditions such as adverse weather. No credit for this procedure is taken in this analysis.

Although not considered as an initiator in the AC reliability model, there is the possibility that a design basis LOCA can occur simultaneously with a loss of offsite power. The combination of a LOCA and a conditional loss of grid is estimated to be near the threshold of 10^{-7}, below which accident sequences are not considered credible. Thus even though the GTGs do not provide a viable response capability for this event, the requirement for AC onsite power reliability is minimal; and the AC power system would be sufficiently reliable even with one D/G out of service.

Failures to start the gas turbine generators can result from failure of the gas turbine ignition system, failure of the APU start units or failure of the operating staff to effectively follow the starting procedure. Since the APU units are interchangeable, each unit has the capability of starting all three gas generators.

In Table 4 running reliability of the D/Gs is modeled as being coupled as such failure of one unit during operation could alter the likelihood of the other successfully operating for the duration of the LOSP. For ease of calculation and because common cause failure experience for D/Gs consists mainly of startup problems, a simplified boolean expression for the reliability of both D/Gs is defined in Table 5.

Table 3

DESCRIPTION OF TERMS IN AC POWER SYSTEM RELIABILITY MODEL

GATES

AC	loss of AC power to Division 1 and 2 ESF loads
DG12	failure of both D/Gs to supply power to at least one division of ESF loads for the duration of the LOSP
GT	failure of the backup GTGs to supply power to and at least one division of ESF loads for the duration of the LOSP
GT12 (GT13, GT23)	Failure of GTGs 1 and 2 (1 and 3, 2 and 3) to supply power for duration of the LOSP.
GT1S (GT2S, GT3S)	failure of GTG 1 (2,3) to start or bear load

BASIC EVENTS

LOSP	loss of all offsite power sources to ESF transformers
NRE	conditional probability of not recovering at least one offsite power source from the time of the occurrence of the LOSP to the time when the reliability calculation is made
DG1S (DG2S)	independent failure of D/G 1 (2) to start or bear load (DG2S)
DG1R (DG2R)	independent failure of D/G 1 (2) to continue running for the (DG2R) duration of the LOSP
DG1M	unavailability of D/G 1 (2) due to maintenance and testing (DG2M)
DG2SC	failure of a second D/G to start or bear load given that a first has already failed to do so

Table 3

DESCRIPTION OF TERMS IN AC POWER SYSTEM RELIABILITY MODEL
(Continued)

BASIC EVENTS (Cont'd)

G2RC	failure of a second D/G to run for the duration of a LOSP given that a first has already failed to do so
CBD1V, CB1906	failure of circuit breakers connecting the GTG system with ESF buses to energize
HEGTCB	failure of control room operators to correctly follow procedure for connecting GTGs with the one of the ESF loads
LOSPTC	conditional likelihood that a complete LOSP has been caused by one or more tornadoes from the same storm
TORNGT	conditional likelihood that GTGs have been rendered inoperable by the same event which caused the LOSP
GTIR (GT2R, GT3R)	failure of GTG 1 (2,3) to continue running for the duration of the LOSP
HEGT1 (HEGT2, HEGT3)	failure of GTG operating staff to successfully execute starting procedure for GTG 1 (2,3)
GTI1 (GTI2, GTI3)	starting failure of GTG 1 (2,3)
APU1 (APU2, APU3)	failure of auxiliary power units to provide sufficient starting torque to GTGs
APU12 (APU13, APU23)	conditional failure of both alternate APUs to provide starting torque to GTG given that the preferred unit has not

Table 3

DESCRIPTION OF TERMS IN AC POWER SYSTEM RELIABILITY MODEL
(Continued)

BASIC EVENTS (Cont'd)

HESW12 (HESW13, HESW23)	failure of GTG operating staff to successfully switch sources of startup power to a second APU given that one has failed
GTIM (GT2M, GT3M	GTG 1 (?,3) unavailable due to maintenance and testing.
HESYNC	Failure of GTG operator to successfully synchronize and align a second gas turbine to an ESF bus.
GT2SC (GTISC, GT3SC)	Conditional failure of a second GTG to start given that a first has failed to do so (this uncludes failures of operators to start a second GTG given that they have not used a correct procedure for the first).

Table 4

BOOLEAN EXPRESSIONS FOR AC POWER SYSTEM RELIABILITY MODEL

AC = LOSP o NRE o DG12 o GT

DG12 = DG1S o DG2SC o $\overline{\mathrm{DG1R}}$ o $\overline{\mathrm{DG1M}}$

+ DG1S o DG2R o $\overline{\mathrm{DG1R}}$ o $\overline{\mathrm{DG1M}}$

+ DG1S o DG2M o $\overline{\mathrm{DG1M}}$ o $\overline{\mathrm{DG1R}}$

+ DG1R o DG2S o $\overline{\mathrm{DG1S}}$ o $\overline{\mathrm{DG1M}}$

+ DG1R o DG2RC o $\overline{\mathrm{DG1S}}$ o $\overline{\mathrm{DG1M}}$

+ DG1R o DG2M o $\overline{\mathrm{DG1M}}$ o $\overline{\mathrm{DG1S}}$

+ DG1M o DG2S o $\overline{\mathrm{DG1S}}$ o $\overline{\mathrm{DG1R}}$

+ DG1M o DG2R o $\overline{\mathrm{DG1R}}$ o $\overline{\mathrm{DG2M}}$

GT = CBD1V + HEGTCB + CB1906 + LOSPTC o TORNGT

+ GT12 + GT13 + GT23 + HESYNC

Table 4

BOOLEAN EXPRESSIONS FOR AC POWER SYSTEM RELIABILITY MODEL
(Continued)

$$
\begin{aligned}
GT23 = {} & GT2S \circ GT3SC \circ \overline{GT2R} \circ \overline{GT2M} \circ \overline{GT1M} \\
& + GT2S \circ GT3R \circ \overline{GT2R} \circ \overline{GT2M} \circ \overline{GT1M} \\
& + GT2S \circ GT3M \circ \overline{GT2M} \circ \overline{GT2R} \circ \overline{GT1M} \\
& + GT2R \circ GT3S \circ \overline{GT2S} \circ \overline{GT2M} \circ \overline{GT1M} \\
& + GT2R \circ GT3R \circ \overline{GT2S} \circ \overline{GT2M} \circ \overline{GT1M} \\
& + GT2R \circ GT3M \circ \overline{GT2M} \circ \overline{GT2S} \circ \overline{GT1M} \\
& + GT2M \circ GT3S \circ \overline{GT2R} \circ \overline{GT2S} \circ \overline{GT1M} \\
& + GT2M \circ GT3R \circ \overline{GT2R} \circ \overline{GT2S} \circ \overline{GT1M}
\end{aligned}
$$

$$
\begin{aligned}
GT12 = {} & GT1S \circ GT2SC \circ \overline{GT1R} \circ \overline{GT1M} \circ \overline{GT3M} \\
& + GT1S \circ GT2R \circ \overline{GT1R} \circ \overline{GT1M} \circ \overline{GT3M} \\
& + GT1S \circ GT2M \circ \overline{GT1M} \circ \overline{GT1R} \circ \overline{GT3M} \\
& + GT1R \circ GT2S \circ \overline{GT1S} \circ \overline{GT1M} \circ \overline{GT3M} \\
& + GT1R \circ GT2R \circ \overline{GT1S} \circ \overline{GT1M} \circ \overline{GT3M} \\
& + GT1R \circ GT2M \circ \overline{GT1M} \circ \overline{GT1S} \circ \overline{GT3M} \\
& + GT1M \circ GT2S \circ \overline{GT1R} \circ \overline{GT1S} \circ \overline{GT3M} \\
& + GT1M \circ GT2R \circ \overline{GT1R} \circ \overline{GT1S} \circ \overline{GT3M}
\end{aligned}
$$

Table 4

BOOLEAN EXPRESSIONS FOR AC POWER SYSTEM RELIABILITY MODEL
(Continued)

$GT13 = GT1S \circ GT3SC \circ \overline{GT1R} \circ \overline{GT1M} \circ \overline{GT2M}$

$+ GT1S \circ GT3R \circ \overline{GT1R} \circ \overline{GT1M} \circ \overline{GT2M}$

$+ GT1S \circ GT3M \circ \overline{GT1M} \circ \overline{GT1R} \circ \overline{GT2M}$

$+ GT1R \circ GT3S \circ \overline{GT1S} \circ \overline{GT1M} \circ \overline{GT2M}$

$+ GT1R \circ GT3S \circ \overline{GT1S} \circ \overline{GT1M} \circ \overline{GT2M}$

$+ GT1R \circ GT3M \circ \overline{GT1M} \circ \overline{GT1S} \circ \overline{GT2M}$

$+ GT1M \circ GT3S \circ \overline{GT1R} \circ \overline{GT1S} \circ \overline{GT2M}$

$+ GT1M \circ GT3R \circ \overline{GT1R} \circ \overline{GT1S} \circ \overline{GT2M}$

$GT1S = HEGT1 + GTI1 + APU1 \circ HESW1 + APU1 \circ APU23C$

$+ APU1 \circ APU2 \circ APU3$

$GT2S = HEGT2 + GTI2 + APU2 \circ HESW2 + APU2 \circ APU13C$

$+ APU1 \circ APU2 \circ APU3$

$GT3S = HEGT3 + GTI3 + APU3 \circ HESW3 + APU3 \circ APU12C$

$+ APU1 \circ APU2 \circ APU3$

Table 5
BOOLEAN EXPRESSION FOR LOSS OF D/Gs GIVEN ASSUMPTION OF INDEPENDENT RUNNING FAILURES

$$
\begin{aligned}
DG12 = {} & DG1S \circ DG2SC \circ DG1R \circ \overline{DG1M} \\
& + DG1S \circ DG2R \circ \overline{DG1R} \circ \overline{DG1M} \\
& + DG1R \circ DG2S \circ \overline{DG1S} \circ \overline{DG1M} \\
& + DG1R \circ DG2R \circ \overline{DG1S} \circ \overline{DG1M} \\
& + DG1M \circ DG2S \circ \overline{DG1S} \circ \overline{DG1R} \\
& + DG1M \circ DG2R \circ \overline{DG1R} \circ \overline{DG2M} \\
& + DG1S \circ DG2M \circ \overline{DG1M} \circ \overline{DG1R} \\
& + DG1R \circ DG2M \circ \overline{DG1M} \circ \overline{DG1S}
\end{aligned}
$$

4.1 Reliability Data

The AC power system reliability model discussed in section 2 was quantified using a combination of site specific and generic data taken from a variety of sources. A summary of data sources is shown in Table 6, with details for some data sources and derivation procedures given in the accompanying notes.

The following considerations were used in developing a working data base:

1. diesel generator unreliabilities (start and run) could conservatively be estimated using generic reliability data summaries such as Wash 1400. Also diesel test and maintenance unavailability could be estimated conservatively in the same manner.

2. gas turbine running reliability could be extracted from industrial experience for the same or similar gas turbine units.

3. gas turbine starting reliability as well as APU reliability could be inferred from telephone interviews.

4. unreliability of components such as circuit breakers is estimated using generic reliability data.

5. human error estimates for gas turbine operation are developed using NUREG/CR-1278 as a source of failure rates for individual activities, gross estimates of the number and description of activities involved, and the assumption that procedures will be fully described and rehearsed by the GTG operating srew.

6. Common cause couplings for failure of more than one diesel generator are estimated from compilations of industry data. Common cause running failures for diesel generators and running failure of gas turbines are estimated only on the basis of engineering judgement.

Table 6

RELIABILITY DATA FOR AC POWER RELIABILITY MODEL

RELIABILITY DESIGNATOR	FREQUENCY OF AC POWER, UNAVAILABILITY AS A FUNCTION of TIME AFTER LOSP (hrs)				COMMENT
	0-2	2-6	6-24	24-72	
LOSP, LOSPTC	.1, .95				Section 1
NRE	.98	.85	.40	.08	Section 1
DG1S, DG2S	3×10^{-2}	-	-	-	GGNS RSSMAP
DG1R, DG2R	3×10^{-3}	1.2×10^{-2}	4.5×10^{-2}	1.3×10^{-1}	Based on MTBF of 333 hrs. WASH 1400, Note 1
DG1M, DG2M	6×10^{-3}	-	-	-	GGNS RSSMAP
CBD1V	10^{-3}	-	-	-	WASH 1400
CB1906	10^{-3}	-	-	-	WASH 1400
HEGTCB	5×10^{-4}	-	-	-	NUREG/CR-1278, Note 3
TORNGT	10^{-3}	-	-	-	Qualitative Argument
GT1R, GT2R, GT3R	3×10^{-4}	9×10^{-4}	4.5×10^{-3}	1.4×10^{-2}	Note 2, Note 1
GTI1, GTI2, GTI3	5×10^{-2}	-	-	-	AECM 84/0241
HEGT1, HEGT2, HEGT3, HESYNC	5×10^{-3}	-	-	-	NUREG/CR-1278, Note 3
APU1, APU2, APU3,	6×10^{-2}	-	-	-	Note 4
HESW1, HESW2, HESW3	1×10^{-2}	-	-	-	NUREG/CR-1278, Note 3
APU23C,APU13C APU12C	10^{-3}	-	-	-	Interview, Note 4

Table 6

RELIABILITY DATA FOR AC POWER RELIABILITY MODEL
(Continued)

RELIABILITY DESIGNATOR	FREQUENCY OF AC POWER, UNAVAILABILITY AS A FUNCTION of TIME AFTER LOSP (hrs)				COMMENT
	0-2	2-6	6-24	24-72	
GT2C, GT3C GT1C	10^{-1}	-	-	-	Interview, Note 4
DG1SC, DG2SC	.19	-	-	-	Shoreham PRA
DG1RC, DG2RC	.1	.1	.2	.2	Qualitative Argument
GT15C, GT25C	.15	-	-	-	Comparison of Mecnanical Complexity with D/Gs
GT1M, GT2M	.02				Interview, Norez

Notes for TABLE 6

1. For the range of required operating hours average operating time was used as an operational demand

2. gas turbine failures to start can be estimated in either of 2 ways

   - data from Allison indicates a forced6outage rate of.08/1000 hrs of unit operation, based on 7.6 x 10^6 hours of experience with the 501k unit. This corresponds to a failure rate

   $$f_{FTR} = 8 \times 10^{-5}/hr$$

   - other data also from Allison indicates a unit running availability of approximately 95%. Running availability is interpretable as the amount of time that power could be generated given that it was wanted all the time. As such, scheduled maintenance and other outage sources would be included along with forced outages. Without acknowledging scheduled outages, assuming an average outage time (T) of 48 hours,

   $$f_{FTR} = \frac{u}{T} + \frac{0.5}{48} = 1 \times 10^{-3}/hr$$

   - clearly the contribution of planned outages is therefore an average estimate of $F_{FTR} = 3 \times 10^{-3}/hr$ is used along with a maintenance outage unavailability of .02.

Table 6

RELIABILITY DATA FOR AC POWER RELIABILITY MODEL
(Continued)

(3) A preliminary analysis of human errors associated with gas turbine operation, based on NUREG/CR-1278 is given below.

Parameter	Description of HE	Basis for Interpretation of NUREG/CR-1278	Base Failure Rate	No Recovery	TOTAL
HEGTCB	Failure of Operator to locate and properly rack in CB1906 from gas turbines	single activity, at least 1 check written procedure local indication	1×10^{-3} 5×10^{-3}	5×10^{-2} 1×10^{-1}	5×10^{-5} (R) 5×10^{-4} (C)
HEGT1 HEGT2 HEGT3	failure of remote operator to correctly start, or align GTG with load	multiple activities at least 1 check written & rehearsed procedure, local indicators	1×10^{-2} 5×10^{-2}	5×10^{-2} 1×10^{-1}	5×10^{-4} (R) 5×10^{-3} (C)
HESW1 HESW2 HESW3	failure of remote operator to correctly realign APU to different gas turbine	small number of activities, checked possible, procedure, no local indication	5×10^{-2}	5×10^{-2}	2.5×10^{-3} (R)
HESYNC	Failure of Operator to Synchronize at least two GTGs to ESF bus	some Gasis as HEGTI	1×10^{-2} 5×10^{-2}	5×10^{-2} 1×10^{-1}	5×10^{-4} (R) 5×10^{-3} (C)

R - realistic

C - conservative

Because of the relatively low amount of nuclear industry experience with GTG operations conservative estimates of human error rate are used in the reliability analysis.

Notes for Table 6 (Continued)

(4) Dan Maranacci of Obrien Machinery indicated by telephone conversation on May 2, 1984 the following information utilized in assessing the reliability of APU based starting for the GTGs. For three different starter systems used with the jet engine, the reliabilities are as follows:

o	hydraulic starter system with small diesel and hydraulic transmission	close to 100%
o	AW starter system with compressed air reservoir for startup	approximately 95%
o	jet fuel based starting system	approximately 90%

The Garrett Ind. APUs are not precisely equivalent to any of the above systems. However, Maranacci believed that the APUs would be only slightly less reliable than the compressed air reservoir system. To accommodate this data an unavailability of 6×10^{-2}/d is used for the APUs. The potential for common cause failures was discussed. However, further discussion with Mr. Maranacci did not reveal any reasonable common failure modes. Mr. Maranacci did feel that there may be a strong common mode coupling for gas turbines based on their vulnerability to a variety of fuel and air particulate problems. Hence a conditional failure rate of .15 is accessed for a second GTG failure to run given that a first one has occurred.

4.2 Base Case Reliability Evaluation

The AC power system reliability model for GGNS was evaluated using the data presented in Table 6. To estimate the potential impact of assuming coupled diesel generator running failure an assessment of the probability of losing both diesel generators as a function of time was performed and is summarized in Table 7. Based on the fact that reliability differences were only noted at the longest time periods and that data on common cause failures to run are not generally available, the semi-independent diesel failure model in Table 5 was used in the AC power reliability evaluation.

Reliability of AC power for the base case conditions is summarized in Table 8. The base case power system reliability quantification was performed, with and without consideration of the impact of gas turbines. The resulting AC unreliability does not vary significantly over time, principally because the failure to run probabilities for equipment increase with time while the likelihood of recovering offsite power increases.

The use of only point estimates of reliability data were could have a substantial effect when compared with estimates produced by simulation models.

4.3 Sensitivity of AC Power Reliability

A way to assess the potential importance of equipment reliability problems and modified conditions of operation is to perform a systematic sensitivity evaluation using a reliability model. In truth, the major usefulness of the reliability model is to accommodate the identification of potential impacts of changes in equipment design or performance. A set of sensitivity evaluations were performed using the AC power reliability model developed for GGNS to assess the potential impact of:

1. adverse reliability of the diesel generators in the running mode (i.e., using a failure rate to run $f_{FTR} = 10^{-2}$/hr. This is done in order to accommodate the fact that due to design or fabrication problems the diesel generators may be experiencing "infant deaths; thus experiencing a failure rate of approximately three times the industry average);

Table 7
COMPARISON OF INDEPENDENT DG RUNNING VS. DEPENDENT RUNNING MODELS

DG Reliability Assumptions	UNAVAILABILITY (1/d) OF BOTH D/Gs IN TIME INTERVAL AFTER LOSP (hr)			
	0 - 2	2 - 6	6 - 24	24 - 72
Independent Failures to Run	.006	.007	.011	.30
Dependent * Failures to Run	.006	.007	.018	.040

* A factor of 4 increses in f_{FTR} for a second D/G given failure of a first D/G before 24 hours, followed by a factor of 2 increase up to 72 hours.

Table 8

SUMMARY FOR BASE CASE EVALUATION OF AC POWER UNRELIABILITY AT THE GGNS SITE

PARAMETER DESCRIPTION		FREQUENCY (1/R-yr) OR PROBABILITY (1/d) IN TIME INTERVAL AFTER LOSP (hrs)			
		0 - 2	2 - 6	6 - 24	24 - 72
LOSP	Occurrence of loss of grid	.1	.1	.1	.1
NRE	Likelihood that power to site on at least 1 incoming line has <u>not</u> been recovered	.98	.98	.45	.08
DG12	Probability of losing power from both Div 1 and Div 2 D/Gs	.006	.007	.011	.030
GT	Inprobability of not obtaining continuous source of power from GTGs	.039	.039	.041	.044
AC	Loss of AC Power to Division 1 & 2 ESF loads				
	- D/Gs only	5.9×10^{-4}	6.9×10^{-4}	5.0×10^{-4}	2.4×10^{-4}
	- D/Gs With GTGs as backup	2.3×10^{-5}	2.7×10^{-5}	2.0×10^{-5}	1.1×10^{-5}

2. removal of one diesel generator from service in order to accommodate a thorough inspection and maintenance while the plant is on line;

3. higher than anticipated frequencies of LOSP as a result of uncertainties on the present data base;

4. longer offsite power recovery times as a result of uncertainties in the present data base, and;

5. combinations of all of the above.

The results of the sensitivity evaluation are shown in Tables 9 and 10. Table 9 is compiled for the AC power system, assuming no backup by GTGs; while Table 10 includes the affect of the GTGs.

The results indicate that the AC power system could experience a significant decline in reliability (as much as an order of magnitude) with a single D/G out. Notably the evaluation indicates that maintaining the plant on line with two D/Gs exhibiting early failure tendencies is better than pulling one out of service if the other is good. Most important, however, the evaluation indicates that under all but the most pessimistic of assumptions concerning the frequency of LOSP and recovery times, the addition of the GTGs produces an overall AC power reliability no worse than the base case estimate with no GTGs.

4.4 Affect of Seasonal Variations in Adverse Weather

A basic task of this study was to determine the potential reliability affects of having a plant at power during a period of time when a single D/G is unavailable, compensating for this by having a gas turbine system available.

The principal vulnerability of AC power is to tornado damage. Thus, the effect of seasonal variations in tornadic activity could potentially be important.

In Section 2.0, it was noted that the frequency of tornado damage comprises most of the frequency of offsite power loss; and that the several months, beginning in June, are a relatively benign period for tornadic activity.

The effect of having GGNS at power during the "quiet period" with only 1 D/G available is evaluated in Table 11. Notably, with best estimates of LOSP frequency and time to recovery for this period, the addition of gas turbines produces a significant impact on system reliability; such that if the conditional likelihood of GTG outage due to tornado (along with LOSP) were underestimated by as much as an order of magnitude, the resulting conclusions about the adequacy of AC power would not be affected.

Table 9

SENSITIVITY RESULTS, AC POWER RELIABILITY FOR GGNS (NO GAS TURBINES)

SENSITIVITY CASE	DESCRIPTION	FREQUENCY OF LOSP AND AC POWER LOSS (1/R-yr) FOR INCREASING TIME AFTER LOSP (hr)			
		0-2	2-6	6-24	24-72
0	- BASE CASE, AVG. DGs - Site specific f_{LOSP} - Best estimate P_{NRE}	5.9×10^{-4}	6.9×10^{-4}	5.0×10^{-4}	2.4×10^{-4}
1	- 1 DG out - Site specific f_{LOSP} - Best estimate P_{NRE}	3.8×10^{-3}	4.7×10^{-3}	3.5×10^{-3}	1.3×10^{-3}
2	- 1 DG out - 1 DG high F_{FTR} - Site specific f_{LOSP} - Best estimate P_{NRE}	4.5×10^{-3}	7.3×10^{-3}	7.7×10^{-3}	3.2×10^{-3}
3	- 2 DGs high f_{FTR} - Site specific f_{LOSP} - Best estimate P_{NRE}	6.9×10^{-4}	9.8×10^{-4}	1.5×10^{-3}	1.3×10^{-3}
4	- AVE DGs - $f_{LOSP} = .2$ - Best estimate P_{NRE}	1.2×10^{-3}	1.4×10^{-3}	9.9×10^{-4}	4.8×10^{-4}
5	- 1 DG out - 1 DG high f_{FTR} - $f_{LOSP} = .2$ - Best estimate P_{NRE}	9.0×10^{-3}	1.5×10^{-2}	1.5×10^{-2}	6.5×10^{-3}
6	- AVG DGs - $f_{LOSP} = .2$ - Pessimistic P_{NRE}	1.2×10^{-3}	1.4×10^{-3}	2.0×10^{-3}	3.0×10^{-3}
7	- 1 DG out - 1 DG high f_{FTR} - Site specific f_{LOSP} - Pessimistic P_{NRE}	4.6×10^{-3}	7.3×10^{-3}	1.5×10^{-2}	2.0×10^{-2}
8	- 1 DG out - 1 DG high F_{FTR} - $f_{LOSP} = .2$ - Pessimistic P_{NRE}	9.2×10^{-3}	1.5×10^{-2}	3.1×10^{-2}	4.0×10^{-2}

Table 10

SENSITIVITY RESULTS, AC POWER RELIABILITY FOR GGNS (WITH GAS TURBINES)

SENSITIVITY CASE	DESCRIPTION	FREQUENCY OF LOSP AND AC POWER LOSS (1/R-yr) SHUTDOWN WITH INCREASING TIME AFTER LOSP (hr)			
		0-2	2-6	6-24	24-72
0	- AVG DGs - Site specific f_{LOSP} - Best estimate P_{NRE}	2.3×10^{-5}	2.7×10^{-5}	2.1×10^{-5}	1.1×10^{-5}
1	- 1 DG out - Site specific f_{LOSP} - Best estimate P_{NRE}	1.5×10^{-4}	1.8×10^{-4}	1.4×10^{-4}	5.8×10^{-5}
2	- 1 DG out - 1 DG high F_{FTR} - Site specific f_{LOSP} - Best estimate P_{NRE}	1.8×10^{-4}	2.8×10^{-4}	3.1×10^{-4}	1.4×10^{-4}
3	- 2 DGs high f_{FTR} - Site specific f_{LOSP} - Best estimate P_{NRE}	2.7×10^{-5}	3.8×10^{-5}	6.1×10^{-5}	5.8×10^{-5}
4	- AVG DGs - f_{LOSP} = .2 - Best estimate P_{NRE}	4.6×10^{-5}	5.4×10^{-5}	4.1×10^{-5}	2.1×10^{-5}
5	- 1 DG out - 1 DG high f_{FTR} - f_{LOSP} = .2 - Best estimate P_{NRE}	3.5×10^{-4}	5.7×10^{-4}	6.3×10^{-4}	2.8×10^{-4}
6	- AVG DGs - f_{LOSP} = .2 - Pessimistic P_{NRE}	4.7×10^{-5}	5.4×10^{-5}	8.1×10^{-5}	1.3×10^{-4}
7	- 1 DG out - 1 DG high f_{FTR} - Site specific f_{LOSP} - Pessimistic f_{NRE}	1.8×10^{-4}	2.9×10^{-4}	6.3×10^{-4}	8.8×10^{-4}
8	- 1 DG out - 1 DG high F_{FTR} - f_{LOSP} = .2 - Pessimistic P_{NRE}	3.6×10^{-4}	5.7×10^{-4}	1.3×10^{-3}	1.8×10^{-3}

Table 11

EFFECT of SEASONAL VARIATIONS on TORNADIC ACTIVITY on RELIABILITY of AC POWER of GGNS

SENSITIVITY CASES	FREQUENCY OF LOSP AND LOSS OF AC POWER (1/R-yr) FOR INCREASING TIME AFTER LOSP (hr)			
	0-2	2-6	6-24	24-72
o f_{LOSP} = .1, P_{NRE} = Expected				
- AVG DG performance	5.9×10^{-4}	6.9×10^{-4}	5.0×10^{-4}	2.4×10^{-4}
- 1 DG out, 1 with high f_{FTR}	4.5×10^{-3}	7.3×10^{-3}	7.7×10^{-3}	3.2×10^{-3}
- 1 DG out, 1 with high f_{FTR} GTGs added	1.8×10^{-4}	2.8×10^{-4}	3.1×10^{-4}	1.4×10^{-4}
o f_{LOSP} = .019, P_{NRE} = Expected				
- AVG DG performance	1.1×10^{-4}	1.3×10^{-4}	9.5×10^{-5}	4.6×10^{-5}
- 1 DG out, 1 with high f_{FTR}	8.6×10^{-4}	1.4×10^{-3}	1.5×10^{-3}	6.1×10^{-4}
- 1 DG out, 1 with high f_{FTR} GTGs added	3.4×10^{-5}	5.3×10^{-5}	5.9×10^{-5}	2.7×10^{-5}

5.0 RESULTS ANALYSIS

5.1 Comparisons of GGNS AC Power Reliability with Other Studies

The results of this evaluation are preliminary and are useful for indicating trends and order of magnitude impacts rather than detailed comparisons. It is useful, however, to compare results of this study with other AC power reliability calculations in order to place the resulting AC power reliability at GGNS in perspective as an impact on plant risk.

Results of the preliminary assessment are compared with power system reliabilities in the Shoreham PRA in Table 12. The reliabilities compare reasonably well for the first few hours after the LOSP. At later times, however, the use of a faster offsite power recovery rate and the consideration of repairs for diesel generators reduces the comparative unreliability of the Shoreham system. Normalizing AC reliability for Shoreham by removing D G repair, the reliabilty estimates are comparable.

An additional comparison is made with results of the NRC's study of emergency AC power system reliability (NUREG/CR-2989) in Table 13. Results of the studies compared were not adjusted to account for differences in the calculational techniques. However the resulting reliabilities can still be compared. What is relevant about the comparison with NRC results is that the use of the gas turbine system maintains a comparatively good reliability for GGNS even with one D/G out. Thus even if a detailed analysis modifies the quantitative estimates, the assertion that plant performance is acceptable with 1 D/G out and the gas turbine system used as backings can still be made.

Table 12

COMPARISON WITH AC POWER RELIABILITY AT GGNS
THE SHOREHAM PRA

SNPS PRA AC POWER PARAMETER	FREQUENCY OF LOSP AND LOSS OF AC POWER (1/R-yr) FOR INCREASING TIME AFTER LOSP (hrs)			
	0-2	2-4	4-10	10-24
horeman Unavailability of AC PWR ivisions 1 & 2+	1.4×10^{-4}	5.7×10^{-5}	2.7×10^{-5}	3.0×10^{-6}
NRE++	.52	.28	.23	.06
robability of No DG Repair	.88	.66	.47	.20
djusted AC PWR Unreliability+++	1.6×10^{-4}	8.6×10^{-5}	5.7×10^{-5}	1.5×10^{-5}
C Calculations @ GGNS ith No DG Repair++++	2.0×10^{-4}	2.4×10^{-4}	1.7×10^{-4}	8.2×10^{-4}
C Calculations @ GGNS ith Gas Turbine Backup	7.8×10^{-6}	9.2×10^{-5}	7.1×10^{-6}	3.7×10^{-6}

f_{LOSP} = .082 for the Shoreham site

\+ This is probability for <u>not</u> recovering offsite power for a given time.

++ conditional likelihood of DG repair by given time is taken out

+++ Calculated f_{LOSP} of .034 is used. No gas turbine backup is assumed.

Table 13

COMPARISON GGNS AC POWER RELIABILITY WITH NRC FORECASTS(2)

STUDY	FREQUENCY OF LOSP AND LOSS OF AC POWER (1/R-yr) FOR INCREASING TIME AFTER LOSP (hrs)		
	0	.5	8
GGNS			
- base case	5.9×10^{-4}	5.9×10^{-4}	5.0×10^{-4} (2)
- 1 DG OUT 1 DG high f_{FTR} gas turbine backup	1.8×10^{-4}	1.8×10^{-4}	3.1×10^{-4} (2)
Generic Plant (1)	2.9×10^{-4}	1.9×10^{-4}	1.9×10^{-5}
- 1 of 2 DG Required			
- water cooled			
Nine Mile Point (1)	2.3×10^{-4}	1.5×10^{-4}	1.1×10^{-5}
ANO-1 (1)	9.7×10^{-4}	7.5×10^{-4}	8.6×10^{-5}
Davis-Besse (1)	2.5×10^{-3}	1.5×10^{-3}	7.1×10^{-5}

(1) DG repair included

(2) all data taken from NUREG/CR-2989, except GGNS

5.2 Discussion of AC Power Loss as an Incremental Risk

It is appropriate to place AC power reliability at GGNS in perspective as a contributor to risk, and to assess the following potential impacts on risk:

1. expected AC power reliability at GGNS
2. decreased AC power reliability as a result of equipment reliability problems or taking a D/G out of service
3. modified AC power reliability due to placing one D/G out of service and adding a system of GTGs in place.

To consider the effects of AC power on plant risk, the Grand Gulf RSSMAP is used since it provides a set of probabilistic core melt calculations including core damage frequency estimates and event free sequence contributions.

In the Grand Gulf RSSMAP, the frequency of core melt was assessed as 3.7 x 10-5/R-yr. There were 9 core melt sequences which were initiated by a LOSP. Dominant contributing accident event sequences are the following:

TQUV -	a loss of offsite power followed by a loss of high and low pressure coolant makeup	1.5 x 10-6/R-yr
TQW -	a loss of offsite power followed by a failure to remove decay heat from the suppression pool within 30 hours	6.2 x 10-6/R-yr
TPQI -	a loss of offsite power followed by a failure of 1 or more safety relief valves to reseat, followed by a failure to remove decay heat from the suppression pool	1.6 x 10-6/R-yr

Assuming that the remaining six core melt event sequences identified in the RSSMAP which were initiated by a LOSP contribute less than or equal to 10-7/R-yr to the core damage frequency; LOSP initiated events contribute approximately 25% of the core damage frequency.

Loss of AC power was a major contributor to all three accident event sequences. Of the dominant sequences described, loss of one AC power train or complete AC power loss occurred in no less than 18%, 53%, and 34% of the cutsets for the three accident sequences respectively.

The available cutset information in RSSMAP was used to establish an importance measure for subsystem failures. Although a preliminary review of the RSSMAP cutsets was not sufficient to determine an accurate importance measure, a range of values of importance for one train of the onsite AC power can be estimated as

$$I_{ACT} = (.11 - .22)^{(1)}$$

Using the upper bound on the importance measure and the information available in the equipment failure cutsets presented in RSSMAP, the effects of several operating configurations for GGMS can be evaluated. The results of this evaluation are displayed as table 14.

The results on table 14 indicate

1) that a substantial loss in running reliability of the D/Gs can be tolerated without a significant impact on core melt frequency.

2) that the plant being operated with one D/G out of service may be new or above the design objective of the NUREG 0880 Safety Goals (1x10-4/R-yr), but

3) that the plant operated with 1 D/G out and GTGs available as a backup is clearly acceptable from the standpoint of incremental public risk.

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(1) Using the Vessely-Fussell measure $I_{ACT} = \frac{\text{cutsets w/AC Power Train}}{\text{Probability of Core Melt}}$

Table 14

IMPACTS OF AC POWER RELIABILITY ON CORE MELT FREQUENCY[1]

Condition	Frequency of Core Melt (1/R-yr)
Base Case-Equivalent D/G performance to RSSMAP for GGNS assumed	3.7×10^{-5}
Case where plant is operated with 1 D/G out of service[2]	1.9×10^{-4}
Case where plant is operated with D/Gs exhibiting high rate of failures to run	4.8×10^{-5}
Case where plant is operated with 1 D/G out of service and GTG system available for backup power supply	3.6×10^{-5}

(1) all data based on GGNS RSSMAP Models

(2) normal performance from other D/G assumed