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THE EFFECTS OF FORCED OUTAGES RATES AND LOAD UNCERTAINTY ON THE GENERATION RELIABILITY EVALUATION

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ABSTRACT

In analysis of generation reliability assessment in power systems, the effect of both forced outages, and uncertainties in load forecasting must be taken into consideration. In this paper, the analysis has been evolved from loss-of-load and loss-of-energy probability techniques.

The student-t-distribution method is used to calculate the uncertainty of the forecast peak demand at specified intervals of confidence. The effects of the numbers and the forced outage rates of the generating units have been studied.

INTRODUCTION

Power generation expansion planning starts with a forecast of anticipated future load requirements. Estimates of both the peak demand and the integrated energy requirements are crucial to effective system planning. Forecasting the future is usually based on what has occured in the past, and time-series analysis is the technique of making inferences about the future on the basis of what has happened in the past.

A time-series technique describes the time variations of the variable under consideration as caused by its systematic and random behaviour. If the series has shown a trend in its variations for a long period of time in the past, it can be assumed that the trend will continue in the future and this consistancy is the basis of the study of forecasting.

The model obtained by using the time-series analysis gives a load forecast which excludes the uncertainty of load behaviour. The student-t-distribution method can then be added to calculate this uncertainty at a specified period of confidence limit.

The generation reliability is thus evaluated by load forecasting obtained by using the modified model, and takes into account the effects of: a) the number of generating units and b) the forced outage rates of generating units.

1. TIME-SERIES ANALYSIS

An appropriate statistical technique for load forecasting is time-series analysis. This technique describes the time variations of the variable under consideration as caused by its systematic and random behaviour. If the series has shown some trends in its variation for a long period of time in the past, it can be asssumed that such trend will continue in the future and that consistancy becomes the basis of the study of forecasting. The trend can be represented by a continuous function of time, and the forecast is obtained by extrapolating this trend forward.

Accordingly, the model is in the form

$$YP(t) = TR(t) * S_k * CI \quad (1)$$

where,

- YP is the monthly peak load
- TR the trend function
- S_k the monthly index of k th. month (seasonal index)
- t the time interval
- CI the cyclical and irrigular components

The selected trend function TR(t) is usually the exponential function of the power demand, and is expressed by TR(t) = exp(Bt) (2)
where, Bt represents the estimated load forecast = Y_{est}, and more details for the calculations of the model parameters are mentioned in ref.[1,2,3,4].

To consider the uncertainties of load forecast, another component is introduced which can be computed and added to the estimated load forecast (Bt in eqn. 2) to obtain more accurate values for the load forecast.

This component expresses the effect of load uncertainties and is computed by applying the student-t-distribution method.

2. STUDENT-T-DISTRIBUTION METHOD [4].

This statistical method is used to include the effect of uncertainty in load forecasting. Its value can be calculated by applying the following steps:

a) Calculation of "t" parameter.

This is given by

$$t_{comp} = r\sqrt{(N-2)/(1-r^2)} \quad (3)$$

at (N-2) degree of freedom and some confidence interval, where,

$$r \triangleq \text{coefficient of correlation}$$

$$= \frac{\sum_{i=1}^{N} X_i \ Y_i}{\left[\sum_{i=1}^{N} X_i^2 \cdot \sum_{i=1}^{N} Y_i^2\right]^{\frac{1}{2}}}$$

The calculated value of "t" from eqn.(3) is checked against the tabulated "t" values, to make sure that it is greater than the corresponding tabulated value. If not, then the original model (eqn.1) must be changed.

b) Calculation of load variance "E" .

The total variance of the load function at a month X is given by

$$E = S_{yx} \left(1 + 1/N + \frac{X_i^2}{\Sigma X_i^2}\right)^{\frac{1}{2}} \qquad (4)$$

where,

x the measured load value

N number of intervals

S_{yx} the mean of the deviations squared for a sample of points measured from the estimated regression line

$$\& = \left[\, 1/(N-2) \sum_{i=1}^{N} (Y_i - Y_{est}) \,\right]^{\frac{1}{2}}$$

The confidence level α is defined as the probability that the load will be equal or less than a specified value, and from eqns. 3&4, the component of load uncertainty effect is given by $\pm\, t_\alpha E$, with the +ive sign for maximum load forecast and the -ive sign for the minimum load forecast. Hence, the load forecast is calculated by $Y_{est} \pm t_\alpha E$ instead of Y_{est}. Then,

$$TR(t) = \exp[\, Y_{est} \pm t_\alpha E \,] \qquad (5)$$

Substituting eqn.(5) into eqn.(1), the modified model is represented by

$$YP_{\substack{max\\min}}(t) = TR_{\substack{max\\min}}(t) * S_{\substack{max\\min}}(t) * CI \qquad (6)$$

where,

$$TR_{\substack{max\\min}}(t) = \exp[Y_{est} \pm t_\alpha E]$$

3. GENERATION RELIABILITY EVALUATION [5,6,7,8,9].

The generation reliability is evaluated for the modified model given by eqn.(6). This evaluation has been made by calculation of two indices which depend on the probability of outage capacity of i th. generating unit "PR_i" where,

$$PR = \frac{n!}{r!\,(n-r)!}\, q^{(r)}\, (1-q)^{(n-r)} \qquad \&$$

q = the probability of failure of forced outage rate

r = rate of outage

n = no. of prabablilities for the loss-of-capacity.

These two indices are :

I) Reliability load index (I_L) :

This is given by

$$I_L = 1 - ELRI$$

where,

ELRI = the expected load risk index

$$= \sum_{i=1}^{n} PR_i * t_i / T$$

t_i = the time during which outage capacity c_i will cause a loss of load

T = the total time duration of the considered load duration curve.

II) Reliability energy index (I_E) :

This is given by

$$I_E = 1 - EERI$$

where,

EERI = the expected energy risk index

$$= \sum_{i=1}^{n} E_i * PR_i / E_{an}$$

E_i = the energy curtialed due to capacity outage c_i

E_{an} = the expected annual energy requirement.

4. EXAMPLE WITH REPRESENTATIVE VALUES .

The data used in this example is for a power system similar to the National Unified Power System of Egypt. In a country such as Egypt, weather does not influence the load behaviour significantly, even in the future, since the climate conditions are moderate and consistant in both the summer and winter seasons.

The first step in the calculation procedure using the time series technique is to obtain the necessary historical data. The monthly peak demand data observed in the time period from Jan. 1979 is given in table (1), and taking

IS	= periods / year	= 12	months
N	= number of months of historical data	= 84	"
NT	= number of months for which the peak demand will be predicted	= 360	"
t	= student's -t- distribution from the statistical tables	= 3	

The computed value of the student-t-distribution t_{comp} is equal to 112.8 and is greater than the tabulated value, confirming that the chosen exponent function is suitable for the data under consideration.

The maximum, minimum, and the mean values of the seasonal index with the standard deviation over the months of the year are calculated and given in table (2).

Table (3) illustrates the calculated values of the monthly peak load demand YP for the year 1973, where the cyclical irrigular variation CI has always approached the unity value, fig.(1). The values of the monthly peak load demand for the rest of the period have been computed and plotted as shown in fig.(2), together with the values of the scalar trend TR. It is seen that the scalar trend curve represents a smoothed function for the monthly peak load demand curve. This gives credibility to the data given.

Applying the student-t-distribution method at different values of confidence level α = 80 % and 99.95 %, the values of predicted peak load YP_{max} & YP_{min} are computed and given in table (4), for the year 1981, where the peak load is centered at the middle of the intervals as shown in fig.(3). The fifth column in table (4) represents the values of the predicted peak loads according to the estimated load values in the data given in table (1) and using the time-series technique. The columns of YP_{max} & YP_{min} indicate the values of these predicted peak loads by using student-t-distribution method. The differences between the two cases seen are due to adding the term $\pm t \alpha E$ to the estimated load values. These predicted peak load values are computed for the months of the years 1986 & 1991 .

The expected annual peak demand and annual minimum demand in MW, together with the annual duration and the assumed annual load factor, are given in table (5).

Table (6) includes the proposed generating units being used in the present calculations. For the expected annual peak load (EAPL) of 2610 MW in the beginning of the year 1982, the proposed generating units are chosen as given in table (7) as a case no. 1. Case no.2, is for EAPL value of 5000 MW for the year 1987, with the folloeing units added to the original units in case no.1, to cover the load growth.

no. of units	type & rating	forced outage %
1	N - 1300	11
1	C - 600	4
1	oil - 600	8
1	G.T.- 100	8

The case no.3, where EAPL = 9400 MW for the year 1992, the added units to the used units in case no.2 are :

1	N - 1300	11
1	N - 1000	9
2	C - 600	4
1	oil - 600	8
2	oil - 300	6
3	oil - 150	4
1	C.T.- 50	9
1	G.T.- 100	8

The expected energy risk index has been computed for the three cases and plotted as shown in figs. 4,5&6, respectively.

To study the effect of changing the number of generating units at the same predicted peak load on the reliability indices, the first case is taken into consideration with new proposed generating units given in table (8) instead of those given in table (7). The expected energy risk indices for the two different proposed systems are shown in fig.(7).

5. CONCLUSIONS.

It has been shown that the student-t-distribution statistical technique can be used to compute more accurate values for the predicted loads by modifying the model which is obtained by the application of time-series technique. This modification includes the effect of load uncertainty on the scalar trend value. The modified model can be used to calculate the generation reliability, taking into account the effect of various combinations of generating units which have different forced outage rates. The effect of these combinations on the generation reliability index has been illustrated. It has an important role in this area of investigation and future work will study the effect of compromising the economy and reliability of the plant to obtain the optimum combination of the generating units.

REFERENCES

1. Muth, J.F. "Optimal properties of Exponentially Weighted Forecasts of Time-Series With Permanent and Transitory Components", Journal of the American Statistical Assoc., Vol. 55, 1960.
2. New, W.R. "Load Forecasting on the Electric Power System Part IV System Forecasting Presented at IEEE Summer General Meeting and Nuclear Radiation Effects Conf. Toronto, Canada, June, 1968.
3. Spumberg, E. "Load Forecasting Techniques for Power System Planning", IEEE PES, Winter Meeting, New York, N.Y., Jan/Feb 1974.
4. C.B. Gupta "Introduction to Statistical Methods" ,Viks Publishing House PVT Ltd.,1973.
5. Roy Billinton & P.G. Harrington "Reliability Evaluation in Energy Limited Generating Capacity Studies",IEEE Winter Meeting, New York, N.Y., Jan/Feb 1978.
6. A.D. Patton "Fundamentals of Power System Reliability Evaluation", Reliability Conf. for the Eectric Power Industry, 1977.
7. L. Wang "The Effects of Uncertainties in Forced Outage Rates and Load Forecast on the Loss-Of-Load Probability (LOLP)", IEEE Trans., Power App. & Syst. Vol. PAS-96, no. 6, Nov/Dec , 1977, pp. 1920-1927 .
8. A.D. Patton & A. Stasinos "Variance and Approximate Confidence Limits on LOLP for a Single-area System", IEEE - Trans., Power App. & Syst., Vol. PAS-94, no.4,Jul/Aug, 1975, 1326-1336 .
9. Roy Billinton "Power System Reliability Evaluation", Gordan and Breach Publishers, 1970 .

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	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973	830	815	850	863	844	910	890	882	917	932	881	962
1974	903	920	965	982	952	972	1005	992	1025	1019	1073	1027
1975	1040	1083	1100	1109	1083	1059	1085	1114	1129	1185	1212	1230
1976	1240	1236	1238	1255	1269	1271	1290	1288	1274	1293	1307	1342
1977	1354	1405	1378	1395	1420	1452	1443	1471	1512	1530	1559	1611
1978	1516	1685	1601	1625	1619	1632	1644	1675	1682	1715	1750	1762
1979	1761	1805	1817	1829	1860	1855	1870	1901	1925	1964	1972	1980

Table (1)

Month	SI max.	SI min.	SI mean.	St. Dev.
January	1.0215	0.9623	0.9903	0.0228
February	1.0583	0.9746	1.0154	0.0275
March	1.0257	0.9930	1.0049	0.0126
April	1.0234	0.9911	1.0067	0.0132
May	1.0056	0.9786	0.9937	0.0104
June	1.0016	0.9535	0.9877	0.0175
July	1.0131	0.9624	0.9938	0.0178
August	0.9971	0.9754	0.9893	0.0074
September	1.0178	0.9765	0.9961	0.0168
October	1.0234	0.9823	1.0031	0.0153
November	1.0332	0.9574	1.0039	0.0283
December	1.0375	0.9803	1.0144	0.0225

Table (2)

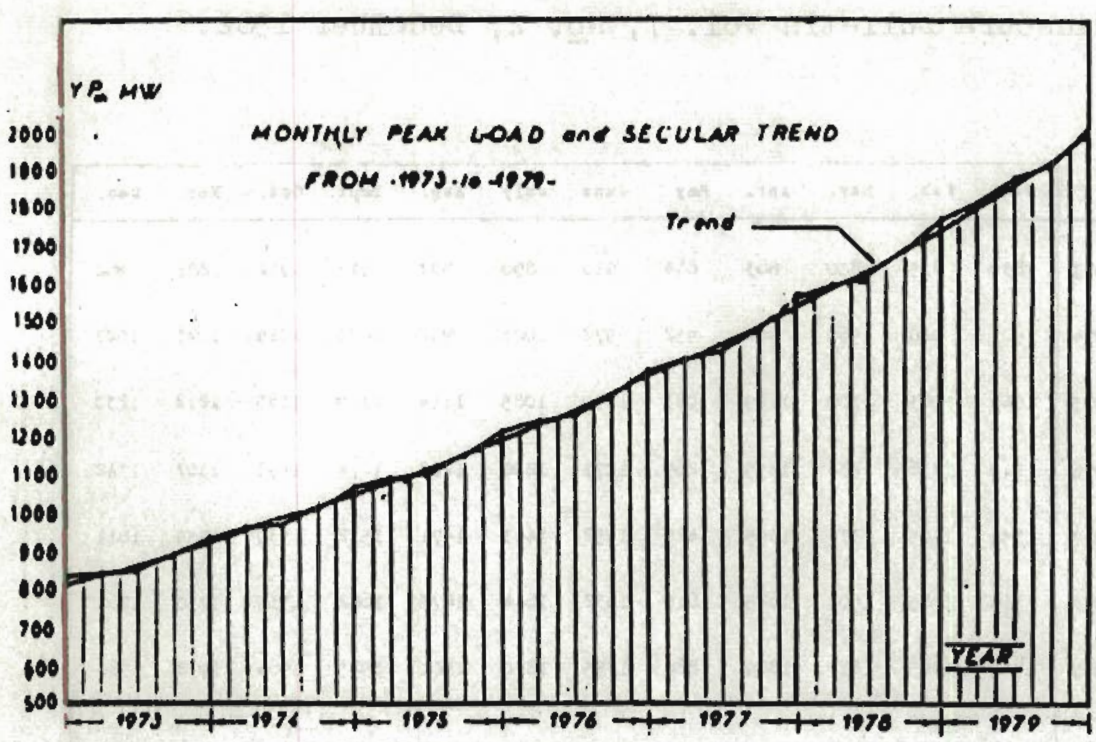
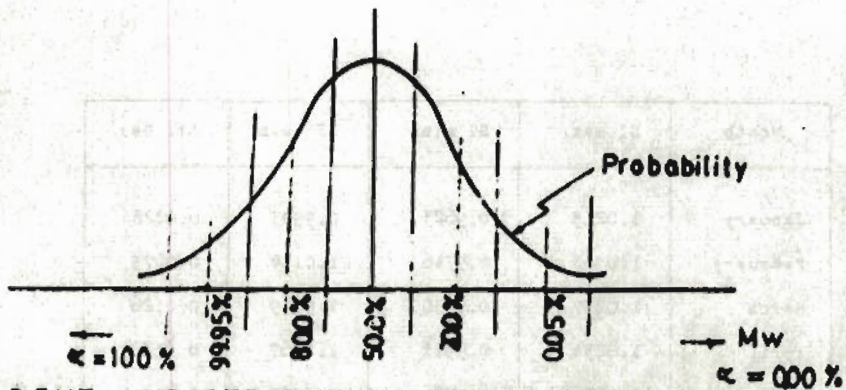


FIGURE (2)



STUDENT - t - DISTRIBUTION FUNCTION of LOAD

fig. (3)

Year	Annual peak Demand in MW (in Dec.)	Annual minimum Demand in MW	Annual load factor	Annual duration in hr
1981	2610.0	1566.0	0.7	8760.0
1986	5000.0	3000.0	0.68	8760.0
1991	9400.0	5640.0	0.65	8760.0

Table (5)

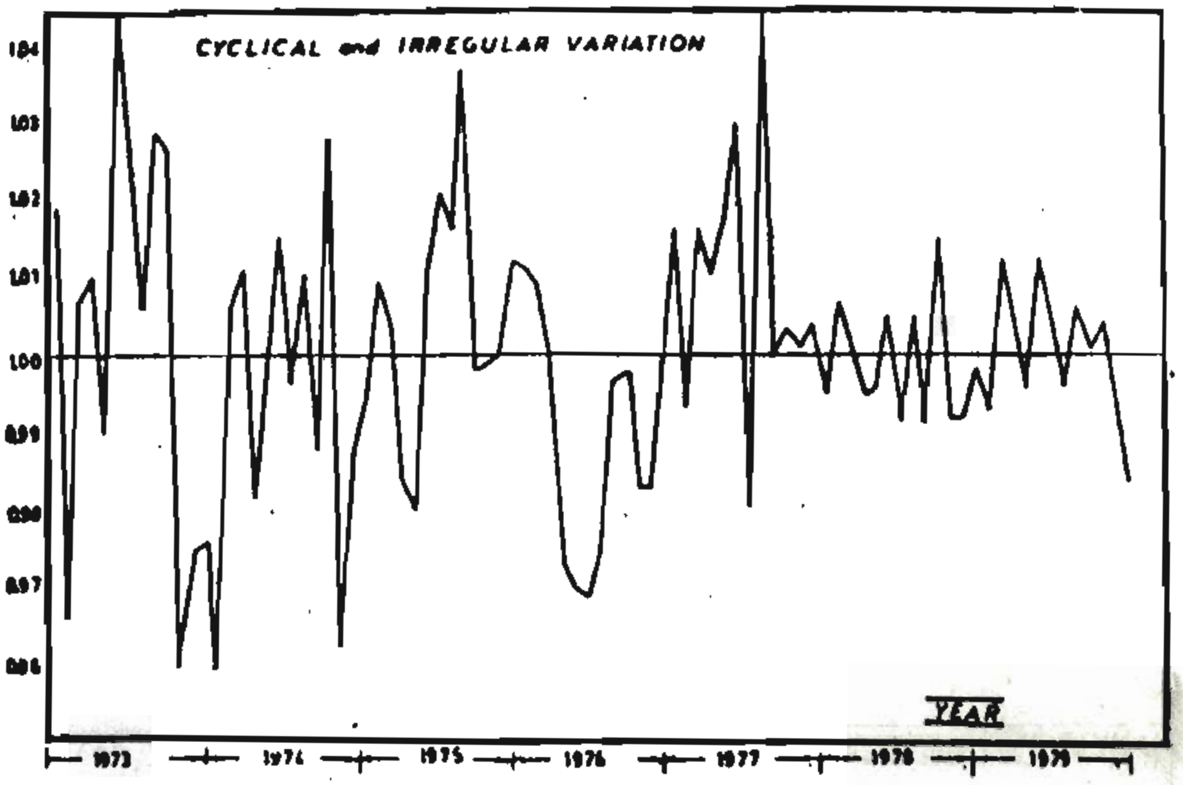


fig. (1)

Year	Month	TR	YP=TR * S	CI
1973	1	822	814	1.019
	2	831	843	0.966
	3	840	844	1.007
	4	849	856	1.01
	5	858	852	0.99
	6	867	896	1.045
	7	876	871	1.021
	8	886	876	1.006
	9	895	892	1.028
	10	905	908	1.026
	11	914	918	0.959
	12	924	938	0.975

Table (3)

Year 1981	YP max. 99.95%	YP max. 80%	TR	TR*S	YP min. 80%	YP min. 99.95%
1	2518	2381	2288	2266	2162	2044
2	2636	2493	2313	2349	2213	2092
3	2583	2442	2338	2349	2278	2155
4	2605	2463	2363	2379	2298	2173
5	2587	2446	2388	2373	2294	2169
6	2605	2463	2413	2384	2299	2136
7	2663	2518	2439	2424	2304	2178
8	2649	2505	2466	2439	2360	2231
9	2734	2584	2492	2482	2388	2258
10	2778	2626	2519	2526	2428	2293
11	2835	2680	2546	2596	2392	2261
12	2878	2720	2573	2610	2476	2340

Type of Unit	Unit's Name	Capacity in MW	Forced-outage Rate
Nuclear	N -1300	1300.0	0.11
Nuclear	N -1000	1000.0	0.09
Oil	Oil- 150	150.0	0.04
Oil	Oil- 300	300.0	0.06
Oil	Oil- 600	600.0	0.08
Gas-turbine	GT - 100	100.0	0.08
Coal	C - 300	300.0	0.04
Coal	C - 600	600.0	0.04
Comb.Turbine	CT - 50	50.0	0.09

Table (6)

No.of Units	Unit Rate in MW	Forced outage rate
1	N - 1000.0	9 %
1	C - 600.0	4 %
3	Oil - 300.0	6 %
3	Oil - 150.0	4 %
1	CT - 50.0	9 %
1	GT - 100.0	8 %

Table (7)

No. of Units	Unit Rate In MW	Forced outage Rate
1	C - 600	0.04
1	Oil - 600	0.08
4	Oil - 300	0.06
3	Oil - 150	0.04
1	CT - 50	0.09
2	GT - 100	0.08

Table (8)

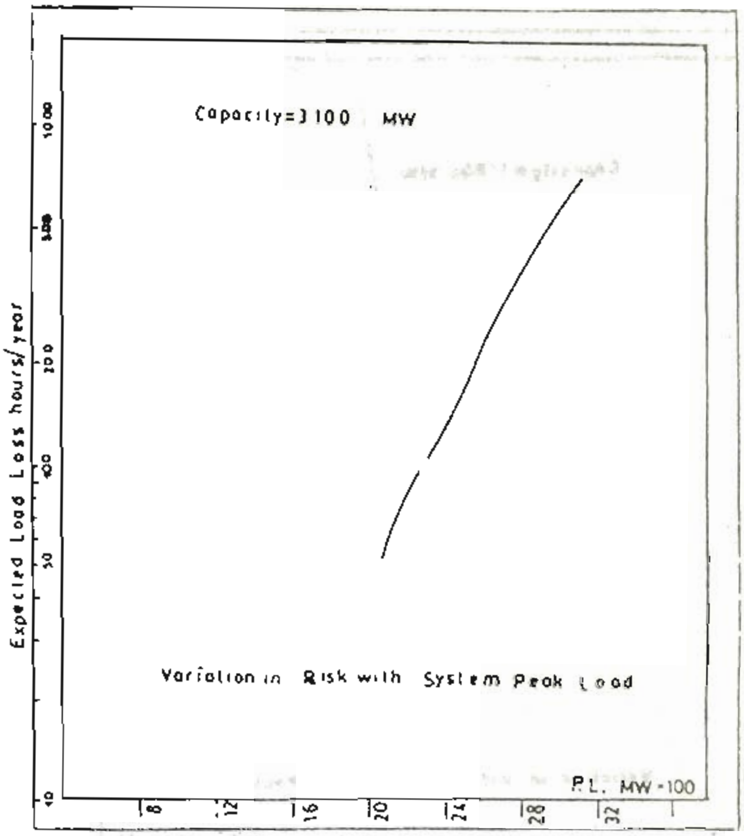

Capacity=3100 MW
Expected Load Loss hours/year
1000
200
100
50
10
Variation in Risk with System Peak Load
P.L. MW-100
8
12
16
20
24
28
32

fig. (4)

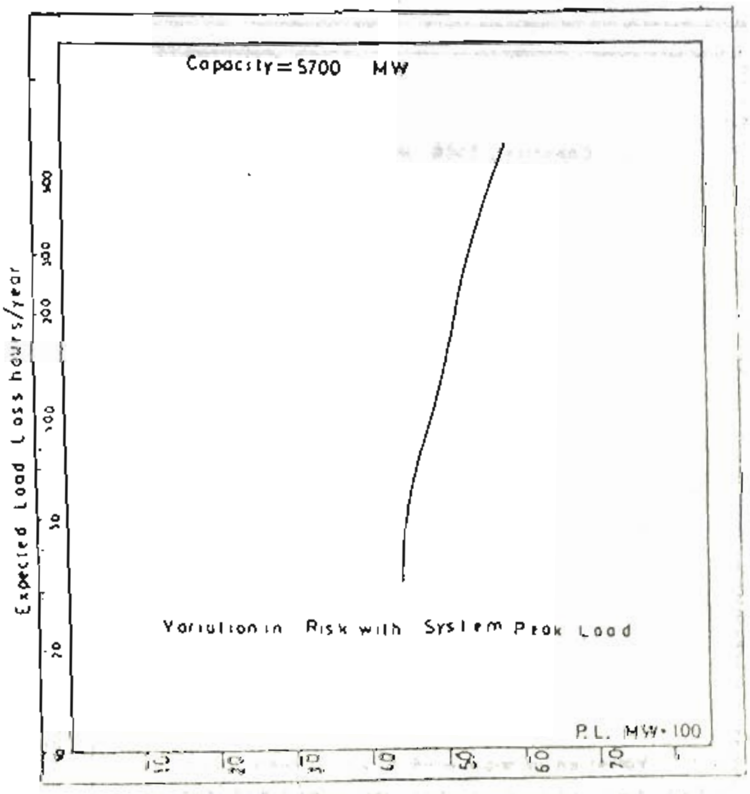

Capacity=5700 MW
Expected Load Loss hours/year
500
300
200
100
50
20
Variation in Risk with System Peak Load
P.L. MW-100
10
20
30
40
50
60
70

fig. (5)

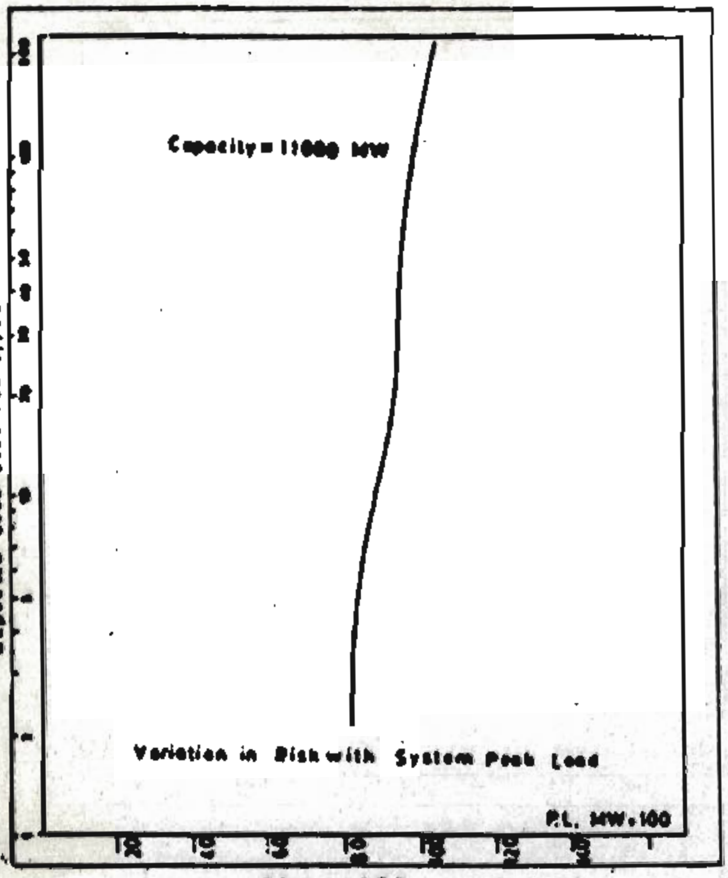

Capacity = 11000 MW
Expected Load Loss hours/year
Variation in Risk with System Peak Load
P.L. MW÷100

fig. (6)

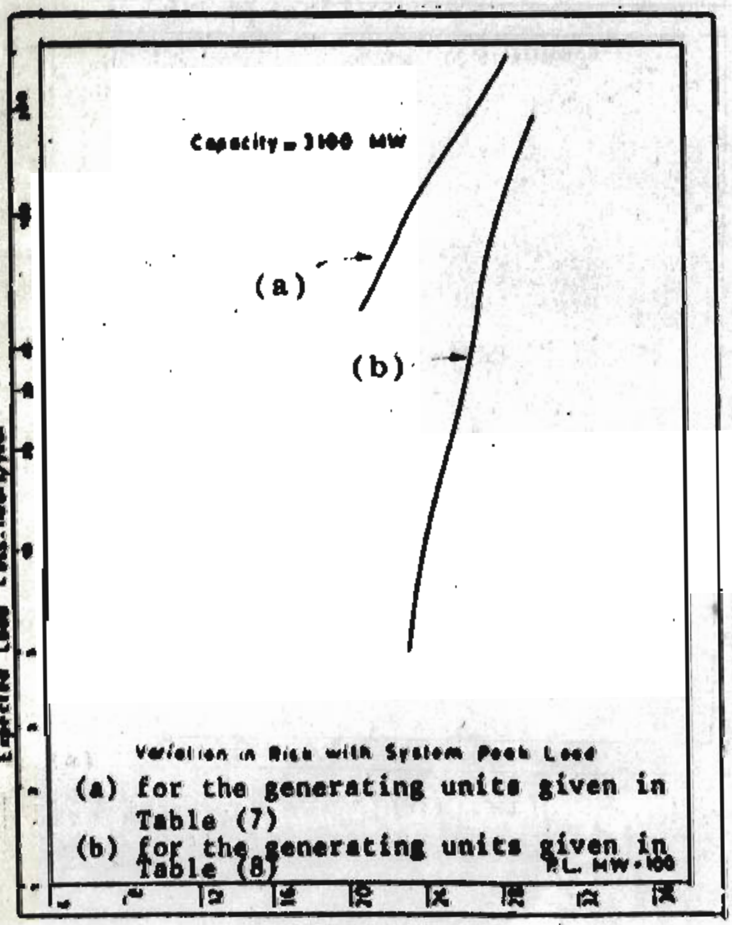

Capacity = 3100 MW
(a)
(b)
Expected Load Loss-hours/year
Variation in Risk with System Peak Load
(a) for the generating units given in Table (7)
(b) for the generating units given in Table (8)
P.L. MW÷100

fig. (7)