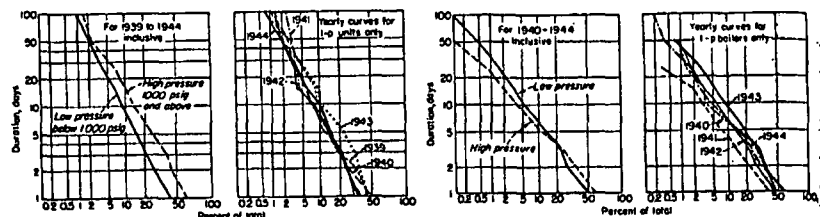
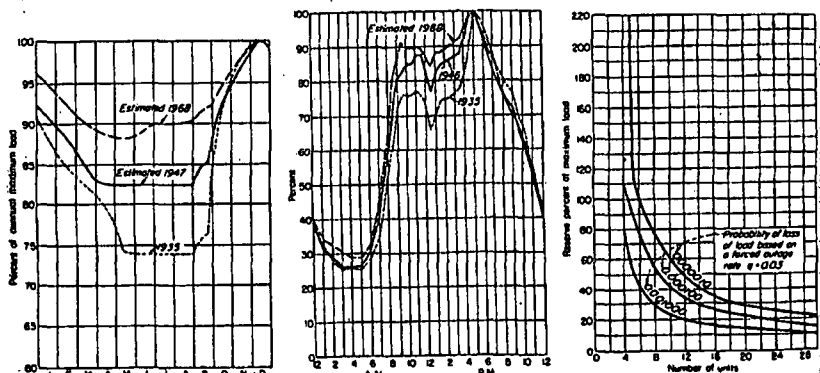


Probability Theory Can Predict Frequency of Future Events



3 Percent total turbine outages with durations greater than indicated value by pressure class and by years 1939-44. 4 Percent total boiler outages with durations greater than indicated value by pressure classes and by years 1940-4.



7 Maximum-day load curve shows growing daily load factor on Con Edison. 8 Reserve needed drops with added units. 9 Probability of loss of load.

them into subgroups of similar units and calculate the outage probabilities of each subgroup, then combine the calculations for each subgroup as shown in Table I, p 104. From Table I a summary of outage probabilities in terms of mw out of service instead of number of units can be calculated as shown in Table II.

Results of such a study for the Consolidated Edison system are shown in Fig. 2. Curve A represents 60 units on the system in 1938 that aggregated 2592 mw with a turbine outage of 0.03, neglecting effect of boilers. Curve B represents expected experience for 1968 with estimated capacity of 3770 mw for the following outage rates: below 1000-psig pressure, turbines 0.01, boilers, 0.015;

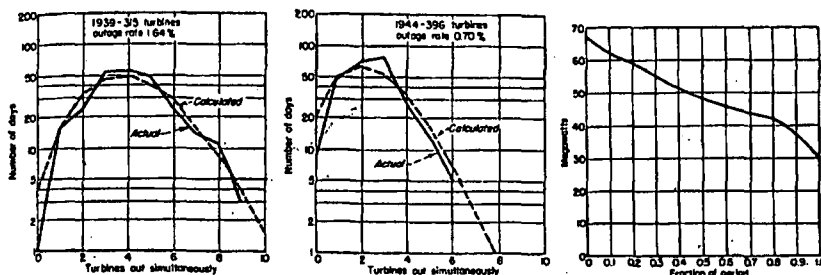
1000 psig and above, boilers and turbines, 0.03.

While these outages are expressed as a given fraction of time, they must not be interpreted to mean that this exact fraction will occur every year. Rather, over a long term of years the various values of outage time will average at the calculated magnitudes.

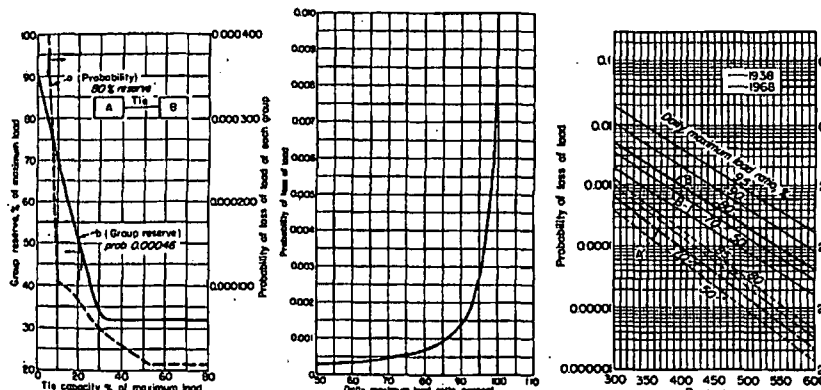
Outage Duration. Probability calculations give no information on the durations of individual outages. This can only be obtained from past experience. Fig. 3 and 4 summarize experience on a large number of units canvassed by the EEL. This type of information is of importance to the planning engineer, especially where hydro plants with storage reservoirs are involved.

Once the outage rate is known it becomes possible by means of the binomial formula to calculate the expected duration of simultaneous outages. Validity of the method can be checked against actual experience as shown in Fig. 5. These curves demonstrate the adequacy of the method for use in engineering planning, provided the data are properly interpreted.

Loss of Load. Having calculated the mathematical relationship of outage magnitudes and their probability of occurrence, next step is to compute the probability of loss of load for a given system of reserve. This is done by appropriate correlation of the probabilities of outage (Fig. 2) with the load-duration curve (such as Fig. 6).



5 Close agreement of calculated and actual distribution of combination turbine forced outages validates use of probability theory for engineering applications. 6 Annual load-duration curves are important in measuring unit outages.



10 The capacity between stations marked by affects group reserve requirements. 11 Probability of loss of load increases at accelerated pace with daily load ratio. 12 Probability of loss of load decreases with growing system reserve capacity.

For a discussion of this correlation see AIEE paper No. 47-248, "Generating Reserve Capacity Determined by the Probability Method," by G. Calabrese.

Service Reliability. Having calculated the outage and load-loss probabilities, next step involves choosing a suitable index and fixing the value that will yield the desired degree of service reliability. These indexes can be expressed as: the number of days outage or loss of load per peak season or per year; as one day outage or loss of load in so many peak seasons; expected kw-hr loss per peak season (or year) per kw of installed capacity; expected kw-hr loss per year per kw of maximum load. The probability method assumes that the calculated outages can occur at

any time of the year. But the peak load usually occurs at only one time during a year as shown in Fig. 6, 7 and 8; hence the probability of losing capacity in excess of the reserve at peak time is much smaller than if the peak load persisted throughout the year. On the other hand, equipment must be taken out of service over extended periods for overhauling, so that at times the reserve provided over the peak load is all that is available at lower loads. In view of these considerations it is recommended that the index of reliability be chosen with due regard to the nature of the load-duration curve and overhaul schedule. For a discussion of indexes see AIEE paper referred to previously in this article.

Level of Reliability. Level of reliability chosen depends on local conditions, importance of load, effect of voltage drop, size of system and, last but not least, personal judgment. A useful guide to selecting the level is past experience with outages and corrective measures that can be provided to reduce load when needed.

There are other problems that require evaluation of relative reliability of alternate methods of system development. The probability technique lends itself readily to arriving at an exact economic evaluation from this standpoint. Problems might be of the following nature: What reliability is lost or gained by decreasing or increasing system reserve? By changing the size