Abstract

The primary objective of generation expansion planning is to meet the electrical energy needs of the customers as economically as possible with an acceptable degree of safety, reliability, and quality. Power system planning involves studies to determine the resources required to meet the growth in demand at the lowest possible cost considering environmental and financial constraints. A power utility should meet the demand under a wide range of normal, abnormal, and emergency conditions including the reasonable foreseeable failures and maintenance outages of facilities. This requires some generation system capacity reserve in excess of forecasted demand. The uncertainty associated with future demand projections could make the system facilities inadequate, or excessive and uneconomical, both cases being unacceptable. Purchasing cheaper power from other utility through interconnection is another alternative which improves system reliability.

In this thesis, some studies have been made on generation expansion planning taking into account the above important criteria. The thesis contains a brief research background and objective to the modelling and analysis of some important requirements of generation expansion planning. The proposed techniques are implemented to an existing electric utility for generation expansion.

The key to all generation expansion planning is a good forecast of load that reflects current and future trends, tempered with good judgment. This is quite important for financial success. Undoubtedly, the most obvious deficiency in any expansion plan is and eventually is seen to be, the inaccuracy of the demand forecasts.

Four modules of Artificial Neural Network have been studied in detail, to forecast peak load of two distribution substations. It is observed from the sensitivity analysis that all modules are not valid for all systems. In other words, for a specific

system only a particular module is suitable for load forecasting. It is also found that the predicted results of minimum mean absolute error (MAE) is dependent on learning rate and learning momentum. Using the findings of the sensitivity analysis, various modules of ANN are studied and the most suitable module found is used to forecast yearly peak load of an existing electric utility for fifteen years choosing an appropriate module for the system.

Reliability criterion, the next aspect, is primarily used to determine the required system generating capacity reserve, to operate the system under equipment failures, equipment maintenance, and load variations. Probabilistic methods are used to evaluate reliability of generation expansion plans using stochastic representation of the generating unit failure-repair process, load variability and emergency help from interconnections.

A modified FFT method has been proposed to evaluate the loss of load probability (LOLP) of a power generating system consisting of different types and sizes of unit. This approach uses hourly loads, or any suitable time interval for system demand, for a given period. Out of several properties of FFT scheme, some properties have been used for the reduction of computational complexity. The accuracy of the method has been illustrated using an example. This modified FFT algorithm is applied to IEEE Reliability Test System (IEEE-RTS). The modified approach improves the efficiency in comparison to the conventional FFT method.

Further, another new approach has also been developed to evaluate the LOLP of a power generating system. This approach uses joint probability density function (PDF) concepts to convolve the unit outages and loads of the system. The reduction of computational effort for identical generating units is obtained using the binomial distribution. The method has been illustrated through an example and is applied to IEEE-RTS. This method is found efficient and easy to use as compared to other existing methods. In addition, the proposed approach can simulate multistate representations of generating units at less computational efforts.

Exploiting these advantages of the proposed approach, generation expansion planning of an existing utility has been made based on levelized LOLP for projected future demand.

In generation expansion planning, interconnected system may play an important role on system reliability. Reliability evaluation methodology of interconnected systems is different from that of a single area system. If the available capacity in one geographical region can be transmitted to other regions whenever it is needed without tie line restrictions then and only then, this system may be treated as a single area. Though it is possible to evaluate interconnected systems as a single system with some approximation, but, it is not in practice due to many obvious reasons.

The improved modified FFT scheme, developed for single area, has been extended to evaluate LOLP of two area interconnected power systems. A stochastic procedure for interconnected systems is presented using improved two dimensional FFT IMSL subroutine of Cyber 180/840A mainframe. This method can simulate multi-state generating units without affecting the computational complexity, whereas the computational complexity of other existing methods increases with the increase of number of outage states of generating units.

The joint PDF approach, developed for single area, has also been applied to evaluate LOLP of two area interconnected power system consisting of different types and sizes of generating units considering independent as well as correlated system demands. The Probability Density Function (PDF) of equivalent load is obtained by convolving the PDF of generating unit outages with the PDF of system demands using the proposed approach. The LOLP values of each system are obtained from the PDF of equivalent load. The accuracy of the proposed method has been illustrated using a simple example. The results obtained for IEEE-RTS are compared with existing methods.

In addition, the above approach is also implemented to an existing utility for which expansion planning studies were carried out. The system under study is considered to be interconnected with a hypothetical system. The benefits desired due to interconnection are evaluated and the impact of interconnection on expansion planning is studied.

An efficient approach has been developed to evaluate the expected energy generation, expected unserved energy, production costs (in the thesis production cost is used for fuel cost) and loss of load probability of a power generating system. The expected energy generation of a given generating unit is obtained by evaluating the difference of unserved energy before and after the commitment of the unit. The method can evaluate expected energy generation and production costs of identical generating units at a time. This is not restricted to load duration curves and unit outage density function of any shapes, or size of the systems with a large number of generation units. Multiple generating units with same outage behavior can be committed with system demand efficiently.

The new developed approach has been extended to evaluate the expected energy generation, expected unserved energy and production costs for two area interconnected power generating system. An example and IEEE-RTS have been used for illustration.

Further, the proposed method has been used to evaluate expected energy generation, unserved energy and production cost of the generation expansion plan developed for existing utility under study. Based on the detailed study, addition of generating units for the existing utility has been recommended for the period under consideration.

Reliability index is derived from the estimates of availabilities of generating units, forecasted loads and unit incremental costs. Uncertainty which results in an unacceptable estimates of system reliability is implicit in the estimates of availability of units and forecasted loads. The uncertainty in the availability of generating units is due to the variation of failure data for different reporting sources and fluctuation in environmental conditions. Fuzzy set theory provides *optimistic* and *pessimistic* values of the derived quantities, corresponding to the assumptions of the highest and lowest *possibilities* of concerned events. In many cases, these bounds provide excellent guidelines to the generation expansion planners.

A model has been developed for fuzzy reliability to quantify the effect of uncertainty associated with unit capacity, FORs and the forecast loads on the LOLP of a power generating system. The model has been explained with the help of a simple generation system. Studies are also conducted on the IEEE-RTS to demonstrate effect of uncertainty on system parameters. Effects on the system reliability index due to variation in the amount of uncertainty of the parameters is studied. This proposed model has also been applied to a practical system to predict fuzzy LOLP.