AN INTERACTIVE PROCEDURE FOR SIZING AND TIMING DISTRIBUTION SUBSTATIONS USING OPTIMIZATION TECHNIQUES

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ABSTRACT

This paper defines a mathematical model which simulates the growth of a power system and determines the least cost expansion plan for a system of distribution substations. A new approach employing linear and integer programming is used to optimize the system's substation capacities subject to the constraints of cost, load, voltage, and reserve requirements. The model has been successfully applied to a 1600 square mile urban area served by 70 distribution substations.

INTRODUCTION

The choice of distribution substation rating is the primary concern of distribution system planning. A large urban area is generally served by several distribution substations. The number and location of substations depends on several factors such as load density, geographical limitations, environmental considerations, right-of-way or transmission availability etc.

As the power system expands transformer capacity must be added in economic and practical increments. However, it is unlikely that all distribution substations will become overloaded at the same time. And even if they did a decision must be made as to which substation must be expanded. Expansion of these substations will generally result in excess capacity in some areas.

Thus a further decision must be made as to how this excess capacity can best be utilized. It is possible to relieve some overloaded substations by transferring portions of their load to substations with excess capacity.

In a large system of distribution substations the above process yields an extremely large number of possible choices. For a system of 70 substations with say three expansion possibilities for each (assuming that one of these is to leave the station as is) the total number of combinations is 3^{70}. To determine the least cost alternative which will satisfy the load requirements is not an easy task.

Further the load requirements can be satisfied by installing small increments of capacity at several substations or larger increments of capacity at fewer substations. The latter would result in more redistribution of load among substations than the former. A certain cost must be associated with these load transfers.

Feeder voltage must be maintained within acceptable limits. This can be done by several combinations of feeder size, power factor correction, regulators, etc. In practice, however, the number of choices is limited by company policy.

Lastly the effect of substation loads on the transmission system must be investigated and the cost of required improvements considered in plans for expansion of the distribution system.

Previous Work

Much work[1,2,3,4,5] has been done in the above areas to place a quantitative value on the parameters involved. However, little has been done to show how these parameters interact and how the data may be used in an unified systematic plan for expansion of a real system. To the author's knowledge the work of Baldwin, Montmeat, Shortley, and Benson[5] is the only unified approach to the problem. Most of this work is proprietary information and not generally available. Also, there is no indication that the expansion algorithms used attain optimality.

Objective

The objective of this paper is to define a model that simulates the growth of load and service areas of distribution substations. Data from this model will be used to determine the size and timing of substation expansion or new substation construction. Optimization techniques will be used to determine the least cost plan.

MODEL

A coarse flow chart of the procedure is shown in figure 1. Detailed definition of the model follows.

Data

A Transformer Load Management Program (TLMP) which relates customer kWh usage to kVA demand provides the basic data for the model. This data is used to provide load densities for an M by M grid which overlays the area to be studied. For ease of manipulation on the computer all data is placed in the fourth quadrant of the XY plane and assigned positive coordinates. One data file is required for each year of data. The load density data is modified such that the sum of the load densities equals the sum of the substation loads for each year of historical data.

$$\text{Thus } d_{ij} = l_{ij} \left(\sum_{k=1}^{N} MLk \Big/ \sum_{i=1}^{M} \sum_{j=1}^{M} l_{ij} \right)$$

where a_{ij} = area located at coordinates i and j
i = x coordinate of basic load area a_{ij}
j = y coordinate of basic load area a_{ij}
l_{ij} = kVA load for a_{ij} from TLMP
d_{ij} = adjusted kVA load for a_{ij}
MLk = metered load for substation k
N = total number of substations

Optimum Service Areas

To forecast substation loads based on historical

TRANSACTIONS PAPER

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