Load Estimation in Electric Power Distribution Networks

Ph. D. Thesis

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1. Introduction
The total demand for electricity, or load, on a power system varies as a function of time on both daily and a seasonal basis. An electric utility must construct, maintain, and operate equipment sufficient to meet the peak, or maximum demand level. Peak load is reached only occasionally, and generally occurs for only a few hours at any given time. The total demand seen by an electric utility is the sum of the individual demands of a diverse set of customers; each with a multitude of different electric devices connected to the power system.

The distribution system is particularly important to an electric utility for the reasons of its closeness to the ultimate customer and its high investment cost. The failures that occur on power distribution systems affect customer service more directly than, for example, failures on transmission and generating system, which usually do not cause customer service interruptions. In addition, about 80% of energy losses are created in distribution power systems and they are the reason for about 90% of all interruptions in the energy supply [21].

The essential point in designing and planning power distribution systems is the estimation of the load, because it is considered more important than the other distribution components, which dictate the type of power distribution system required. For example, suppose that the load customers are known, this allows then to be grouped for service from secondary lines connected to distribution transformers that step-down from primary voltage. Then the transformer load distribution is combined to determine the demand on the primary distribution system, which is then assigned to the substation that steps-down the transmission voltage. As a result, we can say that distribution system loads allow the determination of the size and location, or site of substation and the capacity of the associated transmission lines [14]. The expansion of a power system involves a wide range of tasks. The major steps in the long-range planning of distribution systems are: the estimation of future load; the determination of the number, locations, and capacities of future substations; and the planning of the number, route and the capacities of the feeders. Once an estimation of future loads is accomplished, the next step of distribution planning is to determine the location of future substation capacities. Given the results of load
estimation and the future locations of the substations, the overall nature of the future
distribution feeder system can finally be determined.

For the planning and operation of distribution circuits, knowledge of the power
demands of customers and how these demands are diversified in the network are
required. In order to properly analyze the performance of distribution circuits, it is
essential that accurate estimates of power consumption be obtained. Planning
engineers use load estimation to predict load shape on different parts of the
distribution system. These parts may pertain to a specific line section on a
distribution circuit, or they may consist of multiple interconnection circuits.

Availability of information of load data enables the calculation and analysis of
distribution power system more precisely and it is stated to be an essential
requirement. The acquisition of data on power system distribution is complex
because of a large number of nodes and their area distribution. Traditional systems
that used to direct the power distribution system operations, are not adapted for
collecting and transforming a vast amount of data, and do not allow a dispatcher to
utilize the information effectively. In addition to that, the power distribution systems
have a great deficiency of real time measurements, and the large part of information
on elements' load comes only from sporadic measurements carried out in different
time intervals [35]. As a rule receiving nodes are not equipped with stationary
measuring instruments, so measurements of loads are performed sporadically. In
Poland, for example in operational practice, load data for the performance calculation
and analysis of distribution systems are usually acquired from the power utility
operation staff. The load is evaluated on the basis of the staff utility knowledge as a
result of sporadic measurements of receiving transformers' peak load and data on
customers supplied from transformers [27].

In Jordan, for example, presently there are no permanent recording meters below
the 132/33 KV substations and consumer energy consumption by hours is not
measured except for certain very large consumers. Demand meters at 132/33 KV
substation (except those serving JEA retail loads) record the integrated demand at
30- minute intervals on the mxiprint equipment. Although kilowatt-hour meters exist
at distribution and consumer substations there is no pattern of systematic collection
and use of the information. In particular, there is lack of real time measurements (either instruments or on-line measurements) and therefore it is difficult to evaluate the load in a proper model. Engineers make some assumptions, mainly in load, or they use their experience, but this creates unacceptable errors.

The most popular coefficient factors used by engineers to estimate the load on the distribution power system are the Diversity factor \((D_f)\) and KWHR-to-peak-KW conversion factors \((C_p)\).

If all customers supplied by a utility were to simultaneously demand electricity the load would be far greater than the utility could supply. Load diversities among customers enable the utility to meet the demand. The diversity factor \((D_f)\) is defined as the ratio of the sum of the individual maximum demands of the various subdivisions of a system, to the coincident maximum demand of the whole system [51]. In practice, this factor is used to calculate the load, especially the peak load for distribution transformers and the other parameters of the power distribution system such as transformer sizing, conductor size, peak load demand period, and capacitor banks ratings. The KWHR-to-peak-KW conversion factors or \((C_p)\) is defined to be the sum of all individual customer peaks divided by the total energy usage of the group over a given period. In general, the only information commonly available regarding loads at locations, other than distribution substations and major equipment installation, is billing cycle customer KWHR consumption. This energy data has been used to formulate estimates of loads on distribution circuits by applying KWHR-KW conversion factor, or C-factors. This technique works well for homogenous loads, but problems occur when the customers mix on the system is non-homogenous [41].

Load research data provide an important input to load estimation. The estimation of future load requires an understanding of the characteristics of the various load components. Load research can provide useful information for planning and designing utility distribution systems. Nowadays, with the wide availability of electronic demand records in some other countries for example, USA, Great Britain and France, it is possible for utilities to automatically gather hourly test data for a large sample of diverse classes of customers. These data makes it possible to
calculate diversity factor for more narrowly defined customer classes than was formerly possible, since these classes are more homogenous than all customers taken as a single group.