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THE TECHNICAL AND ECONOMIC CRITERIA TO BE APPLIED IN PREPARING AN ELECTRICITY DISTRIBUTION PROGRAMME

submitted by Union of Producers and Distributors of Electric Power (UNIPEDE)

<u>NOTE</u>: This text is subject to editorial revision.

1. Consumption forecasts

Mr. Gilchrist was particularly interested in the question of consumption forecasts and outlined, in his report, the development prospects in the United Kingdom for the various uses of electric energy. He concludes that the forecasts for lighting and motive power have been very reliable but much less so for heating.

Mr. Forzani's view is that consumption possibilities must be investigated before any network study is begun. This investigation may include the following:

(a) A geographic survey of the area for which the programme is to be prepared;

(b) A study of electricity conditions within the area under consideration and in neighbouring areas, bearing in mind that it is more common to deal with an increase in the level of electrification than with a totally unelectrified region;

(c) Determination of the average density of energy distribution, an estimate of consumption trends and a survey of users' characteristics. This involves establishing the following values on the basis of statistical data: the anticipated number of kWh per km^2 per year to be supplied, classified by principal consumers (e.g., domestic, industrial); and future variations in the density of consumption and in the anticipated maximum values.

(d) Determination of the probable area distribution of loads, with due regard to the nature of the users. This can be based on local conditions, since regulating plans indicate the character of the different areas (e.g., residential, industrial, mixed). This information, together with statistical studies (load, simultaneity and utilization diagrams), indicates the value of the loads and their distribution, the ultimate aim being to draw up maps of the district under study which would include the areas and their various load densities.

As regards the building or development of a network, Mr. Gaussens considers that the purpose for taking each successive decision cannot be solely in order to ensure the most economical supply of the single loads required at the time each decision is taken. Any decision taken at a given moment regarding the development of a network affects all subsequent

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decisions, and each decision depends on the information available at the time it is taken concerning the future trends of loads and of technology.

If the available information were absolutely certain, the optimum series of decisions could be defined as that which minimizes the cost of supply over a sufficiently long period for discounting to render negligible the cost of the installations built towards the end of the period.

As regards the trend of loads and of technology, it is possible only to make forecasts of an uncertain nature based on an extrapolation of the observations made prior to the decisions. Mr. Gaussens considers it reasonable to limit the period under study to some twenty or thirty years. The decision to be taken would therefore be the first of those calculated to minimize the cost of supply during these twenty or thirty years.

In view of the uncertainty of forecasts, a comparison with new elements of information may entail changes in the series of decisions initially selected in order to ensure minimization of the supply cost. If this happens, the decisions already carried out may or may not belong to the series that would have been chosen initially had the new elements of information been available. In the first case, a wrong initial forecast will not have harmful effects. In the second, an irremediable error will have been made, and the only possible action, when adopting a new series of decisions, is to try to ensure a relative minimization of the supply cost. This latter case frequently arises in practice when it is observed that the status of the network is such that its subsequent development cannot take place under the best economic conditions.

2. Network diagrams

Mr. Perrone outlines the development of urban distribution networks since the end of the last century and points out that this development has often been necessitated by the needs of the moment and by the advisability of using existing installations to the maximum. On the basis of his statement, urban networks may be sub-divided into the two following categories:

(a) Networks with two primary distribution voltage levels

(i) Networks whose higher distribution voltage level is between 20 and 35 kV and whose lower level is between 3 and 11 kV. This /group includes group includes the great majority of the major towns in the United Kingdom, whose networks were standardized at 33 kV for the higher and at 11 or 6.6 kV for the lower level. It also covers most German towns, although their standardization is not so advanced as in the United Kingdom as regards voltage values. However, virtually all the values adopted are within the range of 20 to 30 kV for the higher and 4 to 10 kV for the lower level.

(ii) Networks whose higher primary distribution voltage level lies between 50 and 65 kV and lower level between 6 and 15 kV. This group includes most of the larger French urban centres, where the higher level is generally between 60 and 65 kV and the lower between 10 and 15 kV.

(b) Networks with a single primary distribution voltage level

These include most of the smaller French networks (single level, 12 to 15 kV) and some of the German medium-sized urban centres (single level, 6 to 10 kV).

According to Mr. Perrone, the choice of the number and values of primary distribution voltages may be divided into two successive phases. The first and theoretical phase consists in ascertaining the most economical solution for an urban centre with a given type of load distribution and a given power increase curve. Existing installations are considered negligible in the calculation. In the second and practical phase, existing installations are included and the costs of adapting or transforming the network are therefore taken into account.

In the example described by Mr. Perrone, the survey was limited to the Milan and Turin networks. Certain assumptions have been adopted with a view to simplifying the problem, particularly as regards load trends. Mr. Perrone states that the basic data should be the existing loads of the distribution networks and, more especially, their future developments. The latter should be used as a basis for gradating the investments. In the calculations presented, it was estimated that sufficiently authentic results could be obtained by considering conditions such as they might be twenty years hence. In other words, the best solution has been sought by envisaging a given future situation without regard to the dynamics of

/load increases.

load increases.

Another fundamental datum is the network diagram. While acknowledging that such diagrams are an important factor in the economics of a distribution network (investments and operating costs), Mr. Perrone explains that the example studied takes into account only the area diagram of the main trunk lines as this factor is more important for the choice of voltage levels. The results obtained enable him, on the basis of the comparisons, to draw the following two generally valid conclusions:

(a) As regards the structure of the primary networks mentioned earlier, the merits of the three current trends in Europe are equal;

(b) For the primary voltage supplying MV/LV distribution stations, it seems advisable not to exceed 6 to 10 kV for two-level primary networks and 15 kV for single-level networks. Mr. Perrone thinks that it would be a mistake, economically speaking, if these values were exceeded in order to cover the load increase in an existing network.

The report presented by Berliner Kraft und Licht A.G., also included calculations relating to the characteristics of distibution networks (choice of cable cross-sections, power of capacitance banks etc.)

3. Study of the optimum development of networks

This study forms the main subject of the report of Mr. Gaussens, already mentioned in connection with consumption forecasts.

Since the general criterion for selecting the best solution is the lowest cost, the components of this cost must first be defined and then the quality of supply determined. The latter item is essential if the comparison between the different possible solutions is to have any real meaning.

(a) Quality of energy supplied

The two essential characteristics of this supply are continuity of service to users and steady voltage. Different networks may be planned depending on the service interruptions and voltage fluctuations which users normally have to accept. The networks which cost less to build and operate are generally those in which the quality of supply is the worst. To solve this difficulty - juridically at least -, the authorities endorsing the distribution of electric power prescribe, in the relevant regulations, the

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ranges within which the voltage must be maintained and also, although more seldom, the maximum total duration of outage per year. It is generally recognized that the inconvenience resulting from energy not being supplied at a voltage equal to its rated value is proportional to the product of the square of the difference between the voltage actually supplied and that rated by the supplier ($\%^2$ kWh) and, in such cases, it is not uncommon for the energy to be supplied at a more or less variable voltage within the prescribed range. In any network study, it will thus be necessary to take into account the voltage fluctuations expressed in $\%^2$ kWh. Likewise, it will be necessary to determine the engergy (in kWh) that was not supplied because of service interruptions.

This objective definition of service quality does not make the various possible solutions comparable. For this purpose a common measure must be determined linking voltage fluctuations (in $\%^2$ kWh) and service interruptions (kWh), on the one hand, and the expenditure which can be made in order to decrease irregularity in supply on the other.

Bearing in mind the common interest of distributors and users, Mr. Gaussens remarks that service quality should be improved so long as the expenditure involved leads to an at least equal decrease in the money cost of the inconvenience which users experience as a result of irregular service (equality of marginal expenditure and inconvenience). This leads to an evaluation of service irregularity or, more accurately, to a quotation for the $\%^2$ kWh and for the kWh not supplied, in monetary value.

(b) <u>Utilization cost of electricity</u>

The definition of cost should include not only the expenditure on construction, operating costs, etc., but also the amount representing the economic value of irregular service. The latter may be called the utilization cost of electricity. When the utilization cost is at a minimum, it ensures that the solution selected is economically sound and not just intuitively reasonable, because the service provided will be of the quality that the general interest demands.

A comparison between the different chronological series of expenses connected with the projected development of a network may be made by discounting these expenses in relation to a given reference date. When

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seeking the optimum solution, certain rules must be observed which are always of an economic nature and valid whatever the subject of study. These constitute the external logic of the method.

Other rules are used to prepare the way for making a selection from among the innumerable possible solutions. They differ depending on whether the subject of study is an extensive extra-high-voltage system covering a whole country or the low-voltage network of a village. They are the result of reflection and experience and constitute the internal logic of each study.

(c) External logic or economic framework of the method

Any solution for the development of a network may be expressed as a chronological series of power plants or units.

Between changes in its plant, the network is at a given equipment stage which may be described as an inventory. While it remains at a given stage the existence and operation of the network entail certain ordinary expenses, namely, annual capital charges and operating costs, which include the economic value of voltage fluctuation and certain extraordinary expenses, e.g., those resulting from changes in voltage. Finally, when an equipment change is carried out, certain further expenditure (dismantling and modification costs) is incurred.

Once the components of the utilization costs are thus defined, it remains to be seen under what conditions a change in equipment should be carried out. The date for this change is determined as soon as the relevant network data (consumption, statistics of breakdowns, etc.), have been studied and the discount rate fixed.

(d) Cost of a solution or strategy

A solution or strategy is defined as a chronological series of equipment stages. If the dates of change from one stage to another are known (see following paragraph), it is easy to determine the discounted cost of this solution. It is the sum of the discounted values of (a) annual ordinary expenditure (capital charges and operating costs) in relation to the successive equipment stages; (b) extraordinary incidental expenditure; and (c) the dismantling cost, the differential modification costs and the extraordinary amortization costs following a shut-down, which are incurred

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when passing from one stage to the next.

(e) Date of change from one stage to the next

When a change takes place from one stage to the next, the capital charges at the second stage are generally higher than they would have been had the original stage been maintained, and operating costs are lower. In addition, the change entails expenditure for dismantling, differential modifications and extraordinary amortization costs arising from shut-downs.

The rule governing the determination of the date for changing is simple. If it is desired to pass from stage E_i to E_j, this should be done at such a date N_i^j that, by postponing or advancing the change in relation to this date, the discounted cost of the strategy involving E_i and E_j is increased. This may also be expressed by saying that the date N_j^i is that for which the profitability of substituting E_j for E_i is equal to the discount rate fixed for the study.

If it is found that certain operations should have been carried out prior to the initial date of study (negative years of change), it will be necessary, if these operations belong to the optimum chronological series, to undertake them as soon as possible and, theoretically, at the initial date of the study.

(f) Possible strategies

Since a certain number of possible conditions of a network have been chosen, it is necessary, in order to define the optimum strategy, to determine all the consistent chronological series of such conditions and to choose the one which involves the minimum cost. For this purpose, all the optimum dates for the change from one condition to another are calculated and all negative dates are referred back to the initial date of the study.

By listing these dates in increasing order and aligning them with the time-limit of the study, a series may be constructed from which possible strategies may be derived according to the number of changes considered. The number of changes is equal to the number of conditions - 1). It is then sufficient, in order to determine the optimum strategy, to calculate the discounted costs of these different strategies and to compare them.

This problem can be tackled by using electronic equipment. Practical experiments are now being carried out in France prior to the general

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application of the method to the French distribution networks as a whole.

4. Conclusion

The meeting, at which the above points were raised, was the occasion for exchanges of information and fruitful discussion on the economic problems relating to the choice of investments, as they have arisen in Western Europe. Obviously, these problems and their solutions cannot be applied to the Latin American countries, whose level of industrialization is different, without every due precaution. Nevertheless, certain general principles are still valid for countries in process of development and for them the present report may therefore serve a useful purpose.