UNITED NATIONS

ECONOMIC
AND
SOCIAL COUNCIL

LIMITED

ST/ECLA/CONF.7/L.1.35
3 January 1961

ENGLISH
ORIGINAL: FRENCH *

LATIN AMERICAN ELECTRIC POWER SEMINAR

Held under the joint auspices of the Economic Commission for Latin America, the Bureau of Technical Assistance Operations and the Resources and Transport Economics Branch of the United Nations, with the collaboration of the Government of the United Mexican States

Mexico City, 31 July to 12 August 1961

PRICES AND SELECTION METHODS FOR HYDROELECTRIC EQUIPMENT

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NOTE: This text is subject to editorial revision.

* Translation supplied by the Société Grenobloise d'Etudes et d'Applications Hydrauliques (SOGREAH)

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INTRODUCTION AND SUMMARY

The criteria for the selection of new electric power production plants are as a rule laid down by specific departments of private or public enterprises concerned with production problems. The fixing of rates for the sale of power to the public, on the other hand, is the responsibility of other departments which, more often than not, have to obtain Government approval of the rates they recommend. Lastly, production networks are operated by departments not directly concerned with either plant or rate problems.

From an economic point of view, on the other hand, it is deemed essential that the bases on which new plants are selected, their size determined and their sales rates fixed should be similar or at least concordant. Only a high degree of concordance can lead to economic adjustment of the production-consumption system.

While a recommendation would apply to both a thermal or hydro-electric system, they nevertheless differ in one specific feature: the cost price of hydro-electric power is somewhat vaguely defined and prices are widely disparate. Moreover, a hydro-electric site or even a specific plant is highly flexible and likely to produce types of power of varying quality: storage, run-of-stream, daily or weekly flow, peak power, base load periods .... Investment and services may vary considerably depending upon the dam volume and flow decided upon.

The cost price of thermal power, on the other hand, is very rigid and the solution of this problem while constituting one aspect of the previous case, calls for an entirely different set of conclusions.

Thermal-hydro-electric systems are very similar to purely thermal systems and the participation of the latter in the combined system allows both the sales rate and production levels of different types of power production installations to be fixed.

/Chapter I

Chapter I

COST PRICE AND VALUE OF ENERGY IN A HYDRO-ELECTRIC SYSTEM

It will be assumed at the outset that the problem of comparing annual amounts with capital obtained by capitalization at judicious interest rates can be fully solved. Without embarking upon a detailed discussion of a number of questions, some of them bordering on the philosophical, this aspect of the problem will be deemed to have been fully settled.

1. Amount of investment

The various types of plant that can be built in a country with a clearly established topographical structure are characterized exclusively by three variables:

V - storage volume that can be built into each site;

D - dimension of the canalizations.

Even if there are several types of canalization (conduit, tunnel, canal) the diameter (or characteristic dimension in the case of a canal) of each different type in the same site can easily be "coupled" by corresponding values. Price must be considered not in terms of diameter but of load loss and marginal values will have to be taken on these characteristic curves, identical for the various categories of canalization. Each economic dimension of one of the types of works (i.e. a tunnel) then corresponds to a clearly-specified diameter of another type (i.e. a conduit).

- The maximum extractable flow which, at the same time, determines the installed output of the site.

If, in the geographical territory under consideration, A_1, A_2.......A_n is taken to be the specification for each installation the outline of which is assumed to have been defined, the following functions are obtained:

D_{A1} (V_1, D_1, Q_1) D_{A2} (V_2, D_2, Q_2) .....

D_{An} (V_n, D_n, Q_n)

D being the specification for each installation.

/The functions

The functions $_D D_{A1} \quad D_{A2}$ ..... would be specified by means of a technical and financial study made of each site.

A theoretical study of the data on which the specifications are based produces several interesting conclusions:

(a) Price in terms of storage volume always produces, over a certain volume, a marginal price per cubic metre of water which increases and is higher than the average value.

In the case of a volume where this factor is inadequate, it would mean renouncing portions of the storage volume which would be more profitable per cubic metre of water stored.

(b) The price of energy or power gained by increasing the diameter of the canalizations invariably leads to an infinite marginal value as the diameter increases. This happens because the load loss is in inverse ratio to the five power of the diameter.

(c) Conversely, the average price per kW declines as the utilizable discharge of a plant increases.

In most installations it is found that

$$D_{2Q} < {}^{2}{}_{DQ}$$

since the utilizable discharge can nearly always be doubled by building two installations of equal output. For a specific plant, therefore, there is no average minimum cost price for power.

Of course, where use periods are very restricted (in the sense in which this term is explained below) the resulting price per kWh nevertheless rises sharply because of the very limited period in which the funds tied up in excess output are used.

In concluding this paragraph on specifications, it should be pointed out that it is quite useless to speak of the price per kW or kWh of a hydro-electric plant. There are too many variables for this summary rating to have any meaning.

/2. Value

2. Value of energy

Every hydro-electric plant produces kWh the value of which is known to vary considerably. How can this value be defined?

Consumption of electric power is known to vary from season to season (it is slightly higher in winter than in summer in countries with a cold climate), from day to day (it is higher on working days when industrial consumption is greater) and from hour to hour: generally speaking, every network has peak hours when consumers require power and base-load hours when they need very little power.

Let us take two diametrically opposed cases and let us assume, in the first case, that there already is a surplus of power during certain periods. Use of this power by a consumer would cost the community virtually nothing, since the marginal price per kWh in a hydro-electric plant is very low.

During the hours of surplus power the excess must be fully used before any additional power potential can be marketed. The only possible action is to lower the sales rate during those hours. What specific rate below the existing rate can be charged in order to achieve this end?

If the rate is too low, consumption might rise unduly. The demand elasticity curve during the hours of surplus output must therefore be traced.

The rate to be applied corresponds in theory to the intersection of the demand elasticity curve during those hours and the line representing the total potential output of the existing sites.

The resulting price would represent the actual value of the previous surplus output.

In the second case, it will be assumed that there is a shortage of power, i.e., that the full demand cannot be met, and that there is either load-shedding or a refusal to accept new consumers. This is a problem of symmetry similar to the previous case: the value of the energy produced during the period of shortage is higher than that resulting from the rates in force. Here too it would be represented by the intersection of the demand curve and the line representing "current"

/production. This

production. This is the value which should, in theory, be used to fix the power sales price.

The above construction makes it possible to determine the financial "yield" of the use of power eliminated either by an unduly high rate or by shortage. However, without embarking upon the broad area of speculation connected with value, there may be a purely economic aspect to these considerations. All that need be done is to change the definition of the elasticity curve. Whatever the economic system, whether liberal or not, the use of power can always be classified by increasing economic yield. Use the curve obtained by this classification instead of the elasticity curve is all that is required to obtain a purely "economic" definition of the value of the marketable power, similar to the one obtained above.

In short, consideration of:

- the full production potential of the existing network,
- the demand elasticity curves,

determines the power "value" corresponding to the present state of the production and consumption system. This value would be higher or lower than the existing rate, depending upon whether there is a shortage or surplus of power.

The "full" use of the existing system's potential implies ideal use, where in particular the reservoirs would be completely emptied and the plants often used to capacity.

In theory, there are 8,760 power values annually because there are 8,760 elasticity curves.

/Chapter II

Chapter II

CRITERIA FOR SELECTING AND DETERMINING THE DIMENSIONS OF A PURELY HYDRO-ELECTRIC SYSTEM

The problem in theory, is to ensure adaptation to an increasing demand for power of a supply represented by new plants to be "extracted" at the lowest possible cost from the country's water resources.

The following action must therefore be taken:

- new plants selected,
- the size of their three characteristic variables determined.

The specifications of hydro-electric plants have thus been dealt with in general terms and the extent to which these specifications can be influenced by the choice of basic variables has been shown. This is also true of the services rendered, as the following few examples will show.

The first example will be that of a run-of-the stream plant without any reservoir at all. If the hydrological system of this stream is the same as that of the waterways already developed, the surplus output of the plant is of very little interest. The contrary is already true for a waterway with a system quite different from that of most of the waterways feeding the network. It will be assumed, therefore, that a balancing reservoir can be built at very reasonable cost which could store the minimum flow during base-load periods. The excess equipment of the plant could be used both to provide a higher peak load during minimum flow periods and to increase the high-water output, the desirability of which may vary depending upon the hydrological characteristics mentioned above.

Similarly, in the case of an open-air channel, simply by proper planning (horizontal longitudinal sections for banks) the flow of water can be stopped without difficulties of a technical nature, and the reserve lockage water channel used. The plant's peak output is then available even during the low-water period but only for a curtailed period (peak output).

/In countries

In countries such as Norway or Sweden, with very many large lakes, the flow of water can be easily regulated and plants set up at dam sites. Excess equipment does not then cost very much. Under these conditions, there is no reason to curb the tendency of consumers to use peak output since their wishes in this respect can be met at relatively little cost.

Finally, pumpage plants can be built in every country in the world to supply peak power, the cost of these being closely related to each of the proposed sites.

It would be possible, but unnecessary, to give endless examples of how hydro-electric sites can be adapted to serve widely different consumer curves.

Also noteworthy is the fact that although total power consumption lacks elasticity, its distribution over the various hours of the year or, more particularly, of the day is much more flexible.

If there are electro-chemical plants, a measure of elasticity in production will permit an increase in consumption during high-water periods if the price of power is lower; the expense involved can only be determined by the consumer. On the other hand, the daily modulation of this power will at all times be weak for very specific waters as the electro-chemical furnaces are continually in operation. There is also marked elasticity of distribution in domestic consumption: in particular, the power used in the water heaters can easily be shifted to low rates.

The adaptability of consumers and particularly the cost of such adaptation can certainly not be interpreted by methods susceptible of analysis. The problem can nevertheless be adequately resolved by adopting the following procedures:

- demand elasticity curves reflect the measure in which power consumption can be carried over from one hour to the next.

As indicated above, the adaptation of rates by which the full use of power can be ensured at any time defines its value in terms of time and, to some extent, indicates the desirable points on the elasticity curve.

/- there is

- there is no reason to apply to the power produced by new plants a value different from the one thus arrived at for the old plants, unless of course the former represent an enormous output compared to that of the plants currently in operation.

The choice of the plants to be built and their size should be studied, in theory, by applying to the power that can be produced during various periods of the year the values deriving from the rates which, as indicated earlier, should ensure full use of the power produced, without any shortage or surplus.

As for the choice of sites to be developed, those offering a maximum profit potential should be selected.

With regard to size, in view of what was said in Chapter I (a) and (b) on the respective position of marginal and average prices (in connexion with kWh output and the stored volume) the size selected should ensure that the marginal (or fixed, as will be seen later) prices are exactly the same as the rates in force, in accordance with the theory of rate fixing in relation to the cost of development.

If energy price values have been adopted which produce an excess of output over consumption during some hours, the theory is that the rates should, after a time, be lowered in order to absorb the surplus. This would also be economically rational because the hydro-electric potential would reduce the cost price below the current figure.

If, on the other hand, all the power produced, say at high water, cannot be consumed, irrespective of the rate, the economic value of the power is nil and its increase is of no economic interest whatsoever.

The above method of determining size implies that the price of power derives from a market balance, as in the case of any other economic product or asset. The cost price of various qualities of hydraulic power certainly varies more from one site to another than does the cost price of an item towards the manufacture of which several installations have contributed. As in the case of the production-sale balance of any product, only the adoption of a single market price for power production and consumption will lead to a stable balance, a minimum cost price that takes into account the volume of consumption, and the economic use of the potential represented by the water resources concerned.

/Otherwise, if

Otherwise, if different rates were adopted for sales and the selection and size of new plants, it would mean selling a product at a price other than cost. This would entail dislocation of production and consumption which would, in general, be poorly adjusted.

If, on purely economic grounds, for instance, the adoption of rates other than those deriving from cost is desired, a few new elements would have to be introduced which must be defined in the light of the objectives sought in fixing the rates.

The above factors might be applied in a few simple cases:

- First, in the case of a plant with a strictly constant output potential over the year, with no possibility of day-to-day fluctuation.

The total hours in the year are grouped into three categories: base-load hours, full-load hours and peak-load hours, characterized by three elasticity curves.

An inflexible price for power would be irrational because, as consumer demand varies from one group of hours to another, there would either be excess output during base-load periods if the full demand during peak-load hours could be met, or shortage of power at peak-load if the full base-load output was absorbed.

If there were single rates, consumption would be W_p, W_f, W_b, whereas the adoption of P_b, P_f, and P_p rates would ensure consumption of the total power (see Diagram).

The next case might be that of a natural stream with a specific hydrological regime deemed to be similar to that of other streams feeding the same network. The regime will be represented by the classified output curve. The maximum output obtainable from a specific plant is then studied. It will be assumed, too, that the sales price is constant throughout the year. In general, the average price per physical kWh of a plant begins to decline from the minimum flow up to a certain level of output and then increases beyond that minimum value. Thus, if the value of kWh in relation to time were not subject to change, the tendency would be to develop waterways at points where the kWh price is lowest and therefore beyond the minimum flow. This would entail a surplus

/output of

output of no interest to the consumer, who would not find it all useful to change his habits and to consume more of the power produced at high-water, which would then merely have to be diverted elsewhere.

If, on the other hand, a much lower rate is applied to kWh produced beyond the minimum flow period in order to attract consumption of the existing surplus, the rate of development of new waterways should be limited by applying the same rates provided that the physical tendency of the kWh price to decrease is counter-balancec by a lower kWh rate beyond the minimum flow period.

In the example under consideration and again with respect to a purely hydro-electric network, the rate of development of waterways should not be much higher than the minimum flow, except if there is to be a considerable difference in the value of power.

The next example is that of a site, again on a waterway with a constant flow, on which a reservoir can be built in order to store water on a daily basis. The inflow can thus be concentrated over a period of less than 24 hours without increasing production, although this would involve some expense.

In physical terms, the flow can be regulated at any level, from the turbinable volume spread evenly over the day to the concentration of the entire volume within a very short period, subject of course to an increase in the unit price of power. There is no reason why this should not be done if the consumer is in favour and is prepared to pay a surcharge. Otherwise, there can be no heading "Income" next to "Expenditure" represented by the construction of the basin. The size of the plant can only be determined if the extent of the surcharge is known. If several reservoirs, or sites with reservoirs, are built - which is the usual practice - the volume of the reservoirs and the installed capacity can be distributed most effectively. If standard rates are maintained, the cost of the basin would have to be applied against the average price of power. This would eliminate the rational criterion which size is determined and add to the price of base-load power to the advantage of peak-load power; exactly the opposite is needed to balance production and consumption and to limit the cost of plant construction.

/The conclusion

The conclusion is thus reached that there must in any case be a considerable difference in rates depending upon the production-consumption time factor.

1. Some related problems

While it may seem an indisputable fact that energy tariffs must theoretically result from market equilibrium between supply and demand, it is nevertheless equally true that there are still a great many more problems which are none the less important because they remain in the background, and which must be solved if theory is to be applicable in practice.

To begin with, there are certainly 8,760 hours in the year, but it is obviously idle to speak of an elasticity curve for each of them. In practice, it would seem that these hours should be regrouped in categories. Experience shows that in any production system, whether hydro- or thermoelectric, a "critical" period, when production deficiencies would have serious consequences, almost invariably exists. During the rest of the year, owing to the greater productibility of the production system, the value of energy weakens and the marginal requirements left unsatisfied fall to lower levels.

Again, experience demonstrates the importance of subdividing the hours of the day into peak-load, full-load and base-load hours, plus those corresponding to the week-end slack period, which can probably be absorbed into one of the two less heavy of these categories.

This distribution of the 8,760 hours of the year among six categories (three for the critical and three for the non-critical period) may seem to constitute an acceptable scheme for the application of theoretical principles.

But is is for the energy distributed that the producer is paid, and all the expenditure implied by distribution - which may, according to the characteristics of the networks concerned, be of an order of magnitude comparable with that of production costs - must be recompensed.

/Hitherto, whenever

Hitherto, whenever mention has been made of the need for using the same tariffs, the reference has been, of course, to homologous tariffs, since installed capacity tariffs are unaffected, with regard to consumer sales prices, by any distribution charges. Moreover, it is a well-known fact that the cost of a distribution network includes a term proportional to the installed capacity in kW; whence the importance, if only from this standpoint, of the binomial sales price, if, in accordance with theory, the sales price is to reflect the components of the cost price.

In a word, it would be impossible to modify the energy sales tariff to the extent desireable in theory; it is a common practice in France, however, in accordance with the provision relating to river flows, to fix at very short notice the date as from which, at high water, prices will be reduced. Should such adjustments create difficulties, there may conceivably be a need for some degree of dephasing in the changes in the "sales tariff" as related to the "installed capacity tariff", the values taken into account not being entirely homologous. But it is essential that such measures should be temporary and carefully concerted.

Assuming that a solution has been found for these practical problems, there still remains a theoretical difficulty, linked to the method of exploiting water resources. In general, the marginal cost of harnessing these tends to rise; which merely means that priority is given to the exploitation of the best sites, and that the cost of new installations progressively increases. On the other hand, study of the relevant technicques shows that as a rule, with few exceptions, the construction of hydroelectric projects cannot be fractionized. In practice, most works, including those which represent the heaviest expenditure, have to be constructed with a view to their final installed capacity. It has already been shown that, above a certain minimum price, the marginal cost per kWh of the energy produced by a given plant itself rises with the level of installed capacity. In this case, the problem to be solved depends upon the degree of utilization of the water resources available, and on the rate of depletion, that is, on how long the resources in question can be expected to supply expanding consumption.

The solution then consists in determining the dimensions of plant variables in such a way that the marginal price of energy corresponding

/to the

to the values selected is definitely higher than the average figure for each plant, unless, of course, the installation concerned was "fractionizable". Satisfactory utilization of hydroelectric potential would thus be ensured, without adding unduly to the cost of construction of new plants, during a period when the average price of installations is still fairly low. Contrary to appearances, this in no way conflicts with the theory of sale at "development cost". The marginal price of energy in terms of the installed capacity of each head would in effect exceed the average cost, but the "development cost", on the other hand, would be well represented by the average price of the energy produced in the new plants.

But where water resources are on the verge of depletion, it will shortly be necessary to draw upon other sources of power, including thermal energy, and the study of what happens in combined networks may well be of some interest for determining the dimensions of residual hydraulic installations. The "development cost" is then really represented by the "thermal cost", since there is virtually no more hydraulic energy left to be harnessed.

/Chapter III

Chapter III

THE THERMAL OR COMBINED HYDRO-THERMO-ELECTRIC NETWORK

1. The purely thermal network

There is no reason why the above argument should not be applicable to a thermoelectric system; the general solution simply reduces itself to using the same prices for the sale of energy and for the determination of plant dimensions. But the cost of the thermal network is very "rigid". The specific function D (V, D, Q) of each hydraulic works disappears, and is replaced by a much simpler and more general function. The characteristics and costs of a given thermal power station are practically unaffected by the place of construction.

The solution indicated in the foregoing chapter is then merely a matter of calculating sales tariffs on the basis of cost prices, this time much more clearly defined.

Generally speaking, the "production" price (excluding distribution charges, which were considered above) comprises a fixed term corresponding to the construction of the power station, plus a proportional term per kWh produced. To reflect cost prices, therefore, the tariff should include a term proportional to the rated capacity during those hours when the production system capacity is fully utilized (peak load hours), since the increase in consumption during the hours concerned implies the construction of new power stations. Furthermore, it ought, of course, to include a term proportional to consumption for the compensation of expenditure on fuel. Thus the ultimate result would be the use of a binomial tariff for the sale of energy.

The adjustment of production-consumption prices is in this case a one-way process; there is no longer any means of influencing the "production" cost price.

/2. The combined

2. The combined network

The "rigidity" of thermal energy costs also permits considerable simplification of the norms for fixing "installed capacity tariffs", which have to be taken into account in determining the dimensions of hydraulic projects feeding the same network. If the latter are to be worth while, they must produce their energy at a cost price lower than that of thermal energy (possibly calculated on the basis of fuel prices differing from the wholesale price, if it is recognized that this only imperfectly reflects the components of the cost price). It has been seen that the marginal cost of the energy produced by a head increases with the amount that can be produced. The capacity of each head will therefore correspond to a marginal value comparable to the price of thermal energy, due allowance being made for the situation in respect of base- and peak-load hours. As regards the average price, it will of course be lower, in a proportion that will vary in each individual case.

But anomalies may nevertheless arise in relation to certain grades of energy.

(a) Base-load energy

Such energy may be the by-product of a plant whose dimensions were determined with other purposes in view. If a head debouching into a reservoir is over-equipped in order to supply peak-load energy at low water, high water can also be turned to account.

During these periods, the first step will be to put all the thermal power stations out of action. Otherwise, whenever they are in service, hydraulic energy prices will have to include a term corresponding to the cost of operation of these power stations.

If a reserve of producible energy then still exists, it will be possible to fall back on the criterion applicable when plant dimensions are determined on the basis of hydraulic energy alone; a sufficiently low tariff to encourage consumption will be assigned to the energy concerned, and an analogous price will be taken into account in calculating the value of the high-water production of future installations.

/The development

The development of consumption, however, brings an additional criterion into play; the energy which in a particular year is unused may well become consumable even over the short term, since demand doubles every ten years. This is an argument, in cases where non-consumable surpluses are fairly insignificant, for assigning to high-water hydraulic energy, in any event, the minimum price of thermal energy, since within a short period the former will have the same substitution value as the latter. Here again, the sales prices adopted and the homologous prices established for new energy will be such that they neither give rise to a demand which will afterwards have to be satisfied by more burdensome means than the utilization of surplus energy, nor set unduly narrow limits to the production of energy which will shortly be utilizable.

(b) Peak-load energy

A storage plant may now be considered, and its dimensions assumed to have been determined by special geological features. An attempt may now be made to define its dimensions in terms of flow. It may happen, even where the scale of the project is not particularly favourable, that the power cost - i.e., the kW cost of the works producing power (tapping or power stations) - is lower than the cost per thermal kW. Generally, as has been pointed out, in a hydroelectric plant, the marginal value of the power cost progressively decreases; the cost price of material per kW is relatively constant, but that of civil engineering is highly regressive. Consequently, the more the power were to increase, the lower would be the average price per kW, and any basis of comparison with thermal energy would tend to disappear, the gap between prices widening as the level of installed capacity rose.

But lastly, since the volume of turbine water would still be limited by the inflows and the volume of the reservoir, the price of energy would nevertheless increase in terms of the reduction of the annual period of utilization of the plant, until the elasticity curve of peak-load energy consumption were once more reached.

/Here again,

Here again, the criterion for determining plant dimensions in terms of purely hydraulic energy becomes applicable, thermal energy in this case no longer constituting a basis of comparison, since its price is systematically higher than that of hydroelectric power.

This statement relating to a storage volume determined by geological factors can also be shown to be valid whatever the volume of the reservoir; as a general rule, the power cost of the head (tapping plus power station) - analogous to the cost of installation of a thermal power station - can be separated from that of storage in the reservoir, which corresponds, up to a point, to the thermal plant's expenditure on fuel.

3. Evolution of installed capacity norms in a purely hydraulic network

It is now time to revert to the difficulty presented by the hydroelectric site characteristic which has a rising marginal value.

A reminder may usefully be given of the initial phase of equipment, in which consumption still lags far behind the installed capacity for which hydraulic resources are available. This is a very special problem, in which pure economics plays a considerable part; hydraulic plant dimensions must be determined more by strictly economic prospects than by existing data.

Total installable capacity, the cost of which would be lower than that of thermal energy, may be called W, and utilized capacity, already harnessed at a date t, may be indicated by w_o. If r_o is the relation $\frac{w_o}{W}$, the period t_1 during which it will be possible to draw solely upon hydraulic energy (on the assumption that consumption wil be doubled in ten years) will be represented by the following equation:

$$t_1 = 33 \log \frac{1}{r_o}$$

The fact that hydroelectric projects have to be set up with practically no prospect of the installation's being subsequently completed in economic conditions leads to the following consequences in respect of establishment of tariffs and decisions as to equipment.

(a) If t_1

(a) If t_1 were a long period, in the neighbourhood of 30 to 50 years, it would be uneconomic to determine plant dimensions in such a way that marginal characteristics were equivalentto those of the thermal power stations, for it would mean the harnessing of costly blocks of energy, represented by the instalment of surplus capacity at a cost definitely higher than the average figure for other feasible installations. The exploitation of the first blocks of energy, when the available resources were still considerable, would thus be rendered unnecessarily costly. Moreover, a marked degree of uncertainty prevails in this connexion, since no theory enables energy production to be defined too far ahead.

This is the standard case, in which the determination of plant dimensions results from the market equilibrium alluded to above.

(b) Owing to the progressive depletion of resources, the nearer the end of the period t_1, the more closely will the marginal values to be adopted for the determination of plant dimensions and for tariff rates approximate to the values corresponding to thermal projects. They should not exceed them, since this would imply costly, and in the circumstances useless, over-equipment of the hydroelectric sites concerned.

It may be noted, however, that given the very rapid rate of growth of consumption it will seldom be unreasonable to adopt marginal project characteristics equivalent to those of the thermal network. A theoretical estimate could also be made, with the aim of studying the economic boundary-line between the intercalated loads resulting from such over-equipment, and the advantage which would ultimately be derived from it. It is questionable whether such an estimate would have any real significance, in view of the many hypotheses on which it would be based.

(c) Once thermal plants are constructed in considerable numbers - more, that is, than are required on strictly operational grounds (stability of networks, need for production reserves close to consumer centres) - a relatively precise basis is ipso facto established both for fixing tariffs and for determining plant demensions, except in the two special cases indicated above (peak-load and base-load hours).

/CONCLUSION

CONCLUSION

In a purely hydraulic system, decisions as to equipment and the establishment of energy tariffs are the outcome of market equilibrium. It is therefore idle to seek a general method of determining plant dimensions solely on the basis of technical criteria or of the physical characteristics of the works. The search for a method, and its practical application, involve tricky problems; but in any case it is theoretically demonstrable that the study of tariffs cannot be separated from that of norms for the determination of plant dimensions.

At all events, an essential requisite is the availability of numerous statistical data on the current operation of the networks, such as the respective locations of the hydraulic and thermal plants, network load curves, etc. Once again, tariffs must be differentiated in terms of the production situation as regards peak and off-peak hours.

As the harnessing of resources progresses, production tariffs and norms for installed capacity can reasonably be established on the basis of values equivalent to those of thermoelectricity. The problem of determining plant dimensions is greatly simplified, depending merely upon the establishment of technico-economic norms of equivalence.

In the case of certain categories of energy (peak-load, for example), market equilibrium may still exist even in a combined system.

Except in special cases, marginal equalization of prices as between the hydraulic and the classic thermal project will undoubtedly constitute a criterion that is valid at least as a guide.

The inventory of a given country's hydroelectric resources will be an indispensable basis for the study of these different points.

The foregoing data can indubitably be crystallized in relation to each country's individual case, so as to establish a simple and practical procedure for selecting methods of energy production and determining plant dimensions on sound economic lines.