UNITED NATIONS

ECONOMIC
AND
SOCIAL COUNCIL

LIMITED

ST/ECLA/CONF.7/L.2.19
20 December 1960

ENGLISH
ORIGINAL: SPANISH

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

THE CO-ORDINATION OF HYDRO AND THERMAL PRODUCTION: THE SITUATION IN ITALY AND THE EXPERIENCES OF THE EDISON GROUP

by the Edison Group

Note: This text is subject to editorial revision.

CONTENTS

1. Introduction

The problems deriving from the integration of hydro and thermal plants are of tremendous economic importance to countries which produce electric power by both methods. Thus, at the planning stage as well as in the course of execution, the rational co-ordination of both systems of production is essential in order to derive the maximum advantage from power resources and to create a production system that is technically efficient and economically advantageous.

The present report outlines some of these problems and examines, from a general point of view, their principal technical and economic aspects. Subsequently, it deals with the experience of the Italian electric industry in this connection which is of special interest in all its various aspects as Italy, in spite of its extraordinary progress in hydroelectricity, has been faced from the beginning with the problems of hydro and thermal co-ordination because of the steadily increasing importance of thermoelectric production.

The outline which follows will be supplemented by a short résumé of some of the most important achievements of the Edison Group which, with an installed capacity of some 3,500 mW and an annual production exceeding 10,000 million kWh, constitutes the largest electricity enterprise in Italy.

2. The problem of integrating hydro and thermal production

The problem of integrating hydro and thermal production is common to all countries which use both methods, although there are gradations according to the particular situation of each country.

In countries with abundant and technically and economically accessible hydroelectric resources, but with a shortage of fuels, the electricity industry will, as a general rule, concentrate on hydraulic production with the dual objective of taking advantage of the natural resources for the general economic good and of safeguarding, so far as this is possible and convenient, the supply of power from dependence on foreign markets.

In those countries the production of thermoelectricity is generally on a small scale and limited to special work, although in some cases its importance is enhanced by being linked with the need to guarantee continuity in the supply of power at all times. The production of hydroelectricity

/is characterized

is characterized by its close dependence on the available water resources, and it can happen that the supply of water is not at its greatest precisely when there is the biggest demand for electric power. It is common knowledge that the construction of reservoirs of a seasonal character, which store the water intake during some months of the year for use during the months in which the natural supply would not be sufficient to cover consumption, can relieve this situation to some exent.

However, even if this expedient is resorted to, it can still happen that, in a year of exceptionally low water, the storage capacity of the seasonal reservoirs is not sufficient; then it is convenient to have a reserve of thermoelectric plants which can operate in cases of emergency. The functions of the thermoelectric plants need not, however, be limited to mere integration with hydroelectric production in years of exceptionally low water because the total capacity of the reservoirs might be insufficient to ensure adequate seasonal integration even in the years of normal water supply. In this case also, thermoelectric production can be relied on to make up the lack of hydro production in a normal year.

Lastly, the fact must also be considered that most of the hydroelectricity may possibly be generated by running water which cannot be properly regulated; then the thermoelectric plants, apart from effecting seasonal integration with hydro production and constituting a reserve for years of low water, can also be used to meet the "peaks" on the load graphs and, consequently, allowance must be made for sufficient flexibility of service.

The problems of co-ordinating hydro and thermal production may also take on a different aspect, for instance, if the overall production system of a country with hydroelectric resources develops in such a way that, because of the progressive exhaustion of those resources or for other reasons connected with the availability of the different sources of power, the biggest percentage of the total electricity produced is generated by thermal plants. In such cases, the thermal plants are not limited to the secondary role of integration which we have just described, but make a larger contribution, even covering the base of the load graphs. This change of function, as is logical, has an effect on the planning and operation of the thermoelectric installations, and also on the hydroelectric plants themselves.

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But the electric industry in those countries which have water resources does not always concentrate on the immediate utilization of these resources. This occurs only sometimes, for example, in the larger countries where water resources, although abundant, are remote from the centres of consumption, for which reason the cost of transmitting power can be exorbitantly high, at least at first, i.e., until the increase in consumption enables very high tension systems and high transmission capacity to be introduced.

From what we have just said it appears evident that there are a variety of aspects to the problem of co-ordination between hydro and thermal production. Of course the solution of this problem depends on the needs of the supply network, i.e., on the characteristics of the load graphs.

3. Characteristics of the load graphs

As is known, although the graphs or daily diagrams of electricity networks can vary in time and from one country to another, when compared, they generally appear to share some essential features. In order to characterize the power absorbed by a network in accordance with these elements, it is useful to distinguish between the following four categories of power, as shown in figure I, which reproduces, only by way of example, the typical diagrams of minimum and maximum load of the Italian network in the course of the year:

(a) Continuous base power less than the minimum network load on non-working days, and therefore with full annual utilization;

(b) Base power, non-continuous on non-working days, determined by the minimum working-day load. This power is the weekly continuous supply with an annual load utilization of not less than approximately 7,000 hours;

(c) Modulated continuous daily power, corresponding to the part of the load included between the non-working day minimum and that of the "peak" or high point of each meridian curve on the diagram;

(d) Recharged modulated power included in the residual portion of the top of the graph.

The annual utilization of the loads corresponding to the different categories of power apparently decreases in proportion to the increase in the grade of modulation, ranging from 8,760 hours per year for the base to less than 2,000 hours per year for the peak.

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It is especially interesting to examine the curves depicting the duration of the load; these curves, following a uniformly downward trend, are formed by representing on the abscissa for each value of the network load (represented in the ordinates) the corresponding period during the year, that is to say, the number of hours per year during which the network load will reach or exceed this value. The load duration curves on the electricity networks of countries with a certain level of industrialization are characterized by an average utilization of the annual maximum peak load which is more or less 60-65 per cent. There is not usually much difference between them. To simplify, its outline is more or less a straight line. Thus, for example, figure II shows the straight line that approximates the load duration curve for the networks in some countries of Western Europe. This straight line starts at nil duration per load of 90 per cent of the peak load, and reaches full duration per load of 30 per cent. This simplified load graph corresponds exactly to an average utilization of the peak load equivalent to 60 per cent.

The base load, that is full utilization, consequently represents more or less 30 per cent of the maximum peak load, and the base power can be valued at 50 per cent of the total power required. The other 50 per cent of the power required by the network is made up by modulated power. From the simplified graph of duration it will be seen that the average utilization of the corresponding load, more or less equivalent to 70 per cent of the peak load, is about 3,800 hours.

It must also be pointed out that the maximum peak load of a network does not usually co-incide with the total effective power that must be provided for the relevant plants. In order to guarantee a convenient safety margin for every eventuality to cope with any unforseen increase in the load or a breakdown of the machinery or instruments, it is necessary to have plants whose effective power at any moment is greater than the maximum peak load. The effective total power of these plants must be higher still, as part of it will be out of service from time to time undergoing repairs. In practice, the difference between the total effective power of the plants and the maximum peak load that the plants themselves can bear is approximately 20 per cent for networks which are mainly thermal,

/while for

while for hydroelectric networks the difference is generally very much greater.

4. Criteria for using the different types of production plants according to the needs of the load graphs

According to what we have just seen, in the industrialized countries with a large percentage of thermal production, the average utilization of the maximum peak load is more or less equivalent to 60 per cent, and the corresponding average utilization of the total effective power of the plants is approximately 50 per cent, i.e., about 4,000-4,500 hours per year.

In countries at a lower level of industrialization, the average utilization of the effective power of the plants is usually much less.

The foregoing facts, however, refer to the average, which means that there will be plants (base load plants) whose utilization will have to be on a larger scale than the average, and at the same time there will be others, utilized to a lesser extent, which will be used to cope with peaks. In particular, some types of plants which lend themselves to base load operation can be usefully employed at a rate of utilization higher than the average; but, in this case, to be able to cope with the needs of the load graph, it is absolutely necessary that other plants should be available to operate at a level of utilization below the average, that is, that they should be able to cover the peaks of the graph itself.

Unregulated power produced by run-of-river hydro plants can only be used for the base portion of the load graph. On the other hand, with the power produced by hydro plants that have adequate reservoirs it is possible to cope, with the necessary flexibility, with the daily and weekly fluctuations of the load graph and, if the reservoirs have sufficient capacity, the production of run-of-river hydro plants which, as we have seen, is not steady throughout the year because of the different water systems, can be seasonally integrated.

The criteria for planning the plants, both hydro and thermal, naturally vary according to the functions which the plants themselves are called upon to perform within the production system.

We have already shown that thermoelectric plants can make a substantial

/contribution to

contribution to integration in the case of production systems that are in the main hydroelectric, and that they can be utilized on a much greater scale, covering the base portion of the load graph as the quota assigned to thermoelectric production becomes larger.

When the work of the thermal plants is restricted to integration, and arrangements are made to use them on a limited scale annually, the planning criterion will consist essentially in providing thermal units that will result in the greatest saving in the specific costs of installation, although this will imply some limitations in the yield. For this type of work plants of great flexibility are needed that can be started up easily and operate with a variable load. These results can be had with plants with relatively low pressures and temperatures and simple thermal layouts.

On the other hand, for electric power plants which are intended to operate at the base of the load graph, i.e., at a very high rate of utilization, it is more important to obtain high yields, although this involves higher installation costs and more complicated thermal layouts, and, therefore, relatively less operational flexibility.

In a network where the percentage of thermal production gradually increases with respect to hydroelectric until it easily covers the base portion of the load graph, the interest in the different types of storage installations may change. In this case hydro plants which are capable of handling the daily load peaks and the weekly load variations, while the necessity for seasonal compensation decreases, become particularly important. This is a logical consequence of the fact that it is useful to operate the base load thermoelectric plants with an almost constant load during the day, that these plants are available at all times of the year and that - by means of a well-planned outage schedule - the possible irregularities deriving from the water régime in non-regularized hydroelectric production can be offset.

This brief outline of the problems relating to the co-ordination of the different forms of electricity production would not be complete without some reference to the problems which arise from the possible use of electronuclear plants.

An electronuclear plant resembles, in its essentials, a thermoelectric plant. The only difference is that the steam that works the turbines,

/instead of

instead of being generated in a boiler which burns a conventional type of fuel (coal, gas oil, methane), is produced by the heat that fission brings about in the reactor.

A common feature of the different types of electronuclear plants which can be produced today is their very high specific cost of installation which rises rapidly as the unit's installed capacity diminishes. For this reason it is easy to predict that, for the present, only high-capacity electronuclear units for base operation will be able to compete economically with conventional plants.

In order to keep the high installation cost within reasonable limits in relation to the cost of producing energy, it is essential that the annual utilization of electronuclear plants should reach very high levels. Moreover, to ensure that the reactors operate normally and to reduce the costs of maintaining the machinery, the nuclear plants would have to operate (within the limits permitted by the load graph, and depending on the "serviceability" of the plants themselves, about which insufficient experience is available) at a constant load, or at any rate only slightly modulated.

All this understandably restricts the technical possibility of introducing nuclear plants into electric networks; it is only in highly industrialized countries that the demand for power is great and the load graphs show such high volumes that high-capacity plants with a high load factor (if possible) may be established and put to good use.

In any case, the introduction of a base load nuclear fuel plant would prompt the other plants to use the modulated load even more, i.e., to reduce their average utilization.

5. The experience of the Italian electric industry in integrating hydro and thermal production

The problems of co-ordinating hydro and thermal production, which we have outlined, have had to be faced by the Italian electricity industry from its inception.

In Italy, because of local fuel shortages, the electricity industry naturally turned to national water resources. Thus a series of large hydroelectric schemes were embarked upon, thanks to which it was possible

/to cope

to cope with the rapidly growing demand for electricity deriving from industrial development. The rational exploitation of the available and economically accessible water resources within the country also obviated greater dependence on imported fuels, which, because of the great technical and economic difficulties of supply and transport, would have been a serious obstacle to national economic development.

The production of electricity in Italy was in practice limited until 1936 to exclusively hydraulic sources, and the thermoelectric plants played only a secondary role up to that date. In the beginning, the thermoelectric plants were used almost exclusively in emergencies in the case of breakdowns and consequent interruptions in the networks. For this reason they were situated in the immediate vicinity of the principal consumption centres, and were built sufficiently large to handle the load used by those centres. Very soon, however, in the years following the First World War, the thermal plants were given the much more important work of seasonal integration with hydroelectric production for the purpose of making up the water shortages in the years of low water, and fluctuations in the water supply throughout the year.

Thermoelectric production as a base load service was introduced in 1936 following the discovery of geothermic power in an area of central Italy. These geothermic resources are being exploited today almost to their limit and produce a steady 2,000 million kWh approximately, which represents 4 per cent of the total present Italian output.

It was only in the years following the Second World War that thermoelectric production using conventional fuels was introduced into the Italian electricity system as an essential factor in the power economy of the country; it is becoming increasingly important every day. This is evident from a study of the statistical details concerning the magnitude of the thermoelectric quota in the following table. In the period 1951 - 1959, in which an increment of 69 per cent was registered in total production, thermoelectricity expanded by no less than 370 per cent.

The causes of this development can be found mainly in two coinciding phenomena: firstly, the continuous increase in demand; and secondly, the limit of economic use of the available water resources is gradually being approached. The improvement in the supply of conventional fuels on the world market should also be taken into account. Faced with this situation, the Italian electric industry has seized the opportunity of embarking on a gradual process of transformation, among other things, to ensure the more rational use of the remaining precious water resources, greater operational co-ordination between thermal and hydro production, and the progressive and logical conversion of equipment and apparatus in the manufacturing sectors concerned.

PRODUCTION OF ELECTRIC POWER IN ITALY, 1951-59

Year	Total Production (TWh) a/	Percentage Hydroelectric	Percentage Thermoelectric
1951	29.2	90.2	9.8
1952	30.8	87.9	12.1
1953	32.6	85.2	14.8
1954	35.6	82.1	17.9
1955	38.1	80.8	19.2
1956	40.6	77.1	22.9
1957	42.7	74.5	25.5
1958	45.5	79.0	21.0
1959	49.1 b/	78.2	21.8

a/ TWh = 10^9 Wh

b/ Provisional.

This process has been planned in such a way that it will be possible to use, so far as feasible, whatever other source of power there is available in the country, including scanty deposits of poor-quality solid fuels (lignite and peat) and, to the extent possible, marsh gases.

This short outline of the development of the electric power production system in Italy shows how, with water resources being utilized to the maximum, thermal production has been employed in various ways according to the different stages, but always in response to the needs of the moment. The Italian electricity industry has therefore been able to amass a great deal of experience in the matter of co-ordination between hydro and thermal production in all its multifarious aspects.

To illustrate the progress of the Italian production system in its different phases, it might be useful to offer briefly some notes and technical details about the more important installations in Italy set up by the Edison Group.

/6. Conclusions

6. Conclusions

In the foregoing pages we have tried to point out the complexity of the problems relating to the co-ordination of thermal and hydro production which, as we said at the beginning, are of vital interest to all those countries where electric power is produced by both methods.

In particular, we have made it clear that it is not possible to solve these problems by any general formula, but that it is necessary to adopt, in each case, the solution which bears immediate reference to actual national conditions. Nevertheless, the interchange of the experiences of different countries can be of tremendous use in helping to solve these problems and in perfecting the methods used for this purpose. Hence, we have tried to illustrate briefly the most important aspects of the different stages of development of the electricity industry in Italy.

The co-ordination of thermal and hydro production has been undertaken in Italy with a clear understanding of all the factors involved, the great variety of which is evident from the multiplicity of the installations which the Edison Group has built in its eighty years of operation. During this period the Edison Group has accumulated a wealth of experience, not only in planning but also in the construction and operation of the installations, experience from which it has been possible to draw great advantage, not only in Italy but also abroad, especially in many countries of Latin America.

/ Annex

Annex

Some of the principal achievements of the Edison Group in establishing plants for producing electricity

Long ago, in 1883, the Edison Group, the first in Italy and in Europe, began to construct plants for the production and supply of electric power. Their first establishments were small thermoelectric plants in the immediate vicinity of the towns supplied. However, as soon as technical progress enabled electric current to be transported over long distances, the Group concentrated on developing the abundant water resources situated on the borders of the districts supplied. At first it put up installations with a low head, e.g., at Paderno on the river Adda, some thirty kilometres from Milan. With its 10,000 kW and especially with its 13.5 kV cable which connected it with the capital of Lombardy, it was a unique achievement for its time.

The hydrologic and hydrographic situation of Italy is notable for the great lack of homogeneity in its precipitation régime and also for the fact that the drainage areas are broken up into a large number of water-courses with small flows and high heads. For this reason, in Italy, the use of water resources has always necessitated the building of many installations, many of which have large reservoirs and very efficient regulating systems. Right from the beginning, the Edison Group concentrated on this type of construction and thus made rational use of some of the most important basins of the Alps and the Apennines. In accordance with this policy, it began, in 1901, to construct, among others, the plants of the hydroelectric system of the Noce Valley whose installed capacity amounts today to 615,000 kW with an average production of some 1,700 million kWh per year. The power produced by this system is of special interest because it is so well regulated; this system has 16 seasonal reservoirs which can store up to 546 million kWh. The degree of regulation of the basin is thus 33 per cent, which is one of the highest in Italy.

/Another important

Another important example of the entire use of a river basin is offered by the installations that have been completed in the last few years in the high valley of the river Chiese. These very modern works, planned on the basis of the experience gained by the Edison Group over nearly sixty years, consist of three plants built at a series of waterfalls and fed by three reservoirs, two of which are seasonal, with a useful capacity of some 72 million cubic metres, which is equivalent to some 224 million kWh. The annual production of the three plants amounts to an average of more than 620 million kWh. The principal installation is at the second waterfall, with its power plant at Cimego, fed by two diversion galleries, with an installed capacity of 230,000 kW and an annual production of 413 million kWh. In this plant (illustrated in photograph 1), apart from a smaller group engaged in secondary diversion, two groups of 110,000 kW each have been installed (photograph 2), the most powerful of the Pelton turbine type with a horizontal axis in the world. They are notable for their high regulation capacity.

The work of regulation is also carried out by the plants at Santa Massenza and at Santa Giustina-Taio. The Santa Massenza plant, built by the Sarca and Molveno Hydroelectric Enterprise, in which the Edison Group participates equally with the Piedmont Hydroelectric Company, makes use of the drainage of the river Sarca, regulated by Lake Molveno, which has been transformed into a large seasonal reservoir(storage capacity equivalent to over 250 millionkWh); it is the largest hydroelectric plant in Italy as its total capacity is 350,000 kW (see photograph 3). The Santa Giustina-Taio installation, half way down the Noce, is regulated by a large reservoir whose storage capacity is approximately 100 million kWh; the reservoir is formed by a simple arch which is one of the highest in the world (152.5 metres), (see photograph 4). In the underground plant, situated below, there is an installed capacity of 105,000 kW with an annual average output of some 260 million kWh.

Today the Edison Group is building hydroelectric installations with a capacity of about 270,000 kW and an annual output of some 733 million kWh. This programme includes the installations which the Medio Adige Hydroelectric Enterprise, in which the Edison Group has a third part, is

/constructing on

constructing on the island of Serafini in the Po, Italy's biggest river, and those of the Lei Valley on the Italo-Swiss frontier which are being built by an international enterprise with which the Edison Group is also co-operating. The plant on the island of Serafini, the construction of which presented problems, e.g., of not interrupting navigation, which had to be tackled, will have a capacity of 50,000 kW and an average annual output of 305 million kWh. The installations in the Lei Valley constitute a hydroelectric scheme with a very high level of regulation, ensured by a storage reservoir with a useful capacity of 197 million cubic metres, equivalent to more than 500 million kWh, situated at almost 2,000 metres above sea level. The reservoir is formed by a curved dam with parabolic arches. The plant at the first waterfall will also act as a pumping unit for recovering the drainage of the reservoir, and will have a capacity of 185,000 kW and an average output of 234 million kWh.

The Group has also been gathering wide experience of thermoelectric plants through the building of a large series of installations, whose planning criteria reflect the different needs that arose at the time they were constructed.

The old plants at Genoa and Plasencia, built between 1920 and 1940, were planned according to the criteria mentioned in the preceding pages and based on the function of integration that thermoelectric production had to perform in Italy at that time.

Afterwards these plants underwent a radical transformation with the installation of more powerful groups, with features that were adequate to meet the new needs of the production system. In 1952 and 1953, four groups of 70,000 kW each entered into operation in these installations.

The two 70,000 kW groups in the Genoa centre were the first to be put into operation, in accordance with the thermoelectricity plan drawn up in 1948 by the Italian electricity industry with the aim of coping with the ever-increasing demand for more current following the rapid reincorporation of industrial manpower after the war. In the planning of these groups provision was made for a thermodynamic cycle of reheating and regeneration which gave a much higher return than had been hitherto achieved in such installations.

/The groups

The groups at Genoa were immediately followed by two units, also of 70,000 kW each, in the Plasencia plant (see photograph 5), in which planning criteria were applied which, though commonplace today, were, at the time it was projected, something quite new in Italian technique; the solution adopted was that of the "monobloc" whereby a single steam generator is installed in each group with enough power to supply the corresponding turbine. With the "monobloc" system, among other things, it was possible for the first time to reheat the steam after the first expansion of the turbine. This, coupled with other factors, produced a great increase in the yield of the installation. This system was soon adopted in all the other units installed in Edison Group plants.

Recent progress in the technique of construction and the experience acquired have enabled us to use, for the modern group of 160,000 kW (photograph 6) put into operation at the end of 1960 in the Genoa plant, a thermodynamic cycle with even more notable features than those of the older units, with all the consequent advantages as regards the yield of the plant which, it is estimated, could amount to approximately 37 per cent.

In all the thermoelectric installations of the Group the policy followed has been to use all kinds of fuel. This policy derives from the fact that, in Italy, where the supply of coal and gas oil depends largely on foreign imports, the fuel market is very unstable, owing to the economic influence of various geographical, political and physical factors which may suddenly and completely change with time. For these reasons, only if there are plants equipped to use different types of fuel is it possible to guarantee, even at the worst moments, the necessary continuity of supply and to make, so far as possible, the most economic selection of fuel.

A truly daring and internationally interesting initiative is that which the Edison Group has just embarked upon in the construction of a large new thermal installation near the port of La Spezia. At the beginning of 1960, the preparatory work was begun on the construction of a major plant where a 320,000 kW group will come into operation in 1962 and constitute the most powerful turboalternator in continental Europe. In anticipation of an increase in demand, the installation will be enlarged to twice its size in the course of a few years. Another group of equal capacity has already been commissioned.

/The selection

The selection of the specifications for these gigantic groups, each of which will consume per day of operation at full load some 2,500 - 2,600 tons of coal, or some 1,600 - 1,700 tons of gas oil, has demanded a long and careful study of the different technical and economic factors. For the 320,000 kW groups, each one of which will be fed by a steam generator capable of producing no less than 1,000 tons of steam hourly, a thermodynamic regeneration cycle with eight extractors and double reheating has been selected; the steam, generated at a pressure of 168 kg/cm^2 and a temperature of 568°C, will be reheated at 540°C after first expansion in the turbine.

For some time the Edison Group has been turning its attention to nuclear power. Continuous technical developments have obliged it to look far into the future and not to overlook any new possibility.

As we have already said, the costs of producing electronuclear power are still very much higher than those of thermoelectricity produced by conventional fuels. Notwithstanding, the Edison Group has decided to forge ahead with the construction of its first great nuclear fuel plant, recognizing the need to keep abreast of the experience necessary for future developments in the use of this new source of power, experience which only the planning, construction and operation of a new installation can provide.

This new plant, which will be called "Enrico Fermi", will have an effective electric capacity of more than 165,000 kW and will be equipped with a Westinghouse nuclear water-pressure type reactor. The turboalternator, made in Italy, will be larger than any existing European-made single-axle steam turbine of 1,500 revolutions per minute; the rotary part will be over four metres in diameter to correspond with the turbine steam outlet, and the overall length of the turbine-alternator group will be approximately 30 metres.

/SUMMARY

SUMMARY

This report analyses the technical and economic aspects of the problems involved in the co-ordination of hydro and thermal production, which is particularly important in producing electricity by both methods.

By means of short references to the different possible structures of production systems attention is drawn, in the first place, to the functions which thermoelectric production performs in different situations and to the development of those functions when, following the progressive exhaustion of water resources or for other causes deriving from the availability of the various sources of power, the thermoelectricity quota becomes a sizable percentage in the total power produced.

Later the characteristics of load graphs in the electricity networks are dealt with and information is given on the utilization of installations intended to supply base, modulated and "peak" power.

These last considerations offer an opportunity of studying the capacity of the different types of power plants to help in covering the load graph of an electricity network. In this connection special mention is made of nuclear installations. These installations, because of their technical and economic features, their well-known operational inflexibility and high construction costs, will have to be used to supply base loads and, consequently, their operation will compel the other plants to step-up the modulated load on an increasing scale.

The report closes with a brief reference to the experience gained in the co-ordination of hydro and thermal production by the Italian electricity industry; this experience is of wide and singular interest as in Italy, in spite of the extraordinary development of hydroelectricity, it has been necessary from the outset to study the problems of hydro-thermal co-ordination because of the ever-growing importance of thermoelectric production.

Lastly, with the object of illustrating the different phases in the development of Italy's production system, some information and technical details are given on the most important production plants built by the Edison Group.

FIGURE I

GRAFICO I

CHARACTERISTIC LOAD GRAPHS IN THE ITALIAN ELECTRICITY NETWORK

GRAFICOS CARACTERISTICOS DE CARGA DE LA RED ELECTRICA ITALIANA