AN ABSTRACT OF THE THESIS OF

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Title: A Critical Survey of the Electric Power Supply in Greece

Abstract approved: H. G. Barnett
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History, topography, and nature of people have influenced the development of electric power in Greece quite substantially. The power production per capita in Greece is very low as a result mainly of continual wars and an uneven distribution of population.

In 1948, electricity was being supplied in the country only by small independent local companies which were using imported fuel. With the exception of the Capital Area, the service was quite poor and unable to supply the increasing demand for power. The installed capacity was 205,187 KW; however, although this capacity amounts to 32.44 watts per capita, the maximum demand was only 18.11 watts per capita because of inadequate transmission and distribution facilities as well as poorly maintained generating equipment.

In 1948, the Greek Government decided to design and construct a new power system extending all over the country and using, as much as possible, available natural energy resources.

According to this plan, a program was adopted of constructing seven generating stations having a total capacity of 520,000 KW. Five of these plants are hydroelectric projects while the other two are thermal, using locally-mined lignite for fuel. Furthermore, a transmission system, included in the program, will interconnect the above projects and cover the country as well as the areas where industrial development had been limited by a lack of electric power.

The new system was designed under the supervision of Ebasco Services Incorporated of New York and is supposed to cover the power needs of the country as soon as it is

completed. Today, two hydroelectric and one thermal projects are supplying the country with electric energy; the rest are under construction or in the design stage.

The New Power Program adopted a frequency of 50 cycles as well as standard transmission and distribution voltages.

The New Power Program has made a commendable start toward providing the country with a modern power system. A more extensive and more reliable transmission system should be developed as soon as possible. Transmission and distribution voltages should be standardized throughout the country. People should be encouraged to use electricity by reduction of taxes on electricity and appliances. A continuing study of power demand and available energy resources should be made and the system should be adjusted accordingly.

A CRITICAL SURVEY OF THE ELECTRIC POWER SUPPLY IN GREECE

by

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SECTION I, INTRODUCTION

A. Factors Delaying Development in Greece

There are three main factors which, directly or indirectly, have influenced the evolution of conditions related to electric power in Greece. These factors are the history and the topography of the country and the nature of the people.

1. History. Most authorities agree that the history of Greece starts around 1000 B.C. This long history has in the past and still is affecting the development of the country, since the continuous and prolonged utilization of her natural resources has placed her in the following uneconomical position: While other countries utilize only part of their resources to fulfill their needs, leaving the remaining for future advancements and developments, Greece has had to use all of her resources that could be developed by simple and inexpensive methods in order to maintain a relatively low standard of national well-being.

Because of her strategic location Greece has been occupied repeatedly by foreign elements, thus not permitting her to exist as a free nation until 1821. Since then she has been attacked and forced into war four times at intervals of approximately twenty-five years. Besides the human and material destruction that these wars have brought to the country, they have discouraged prospective capital which might develop her resources.

2. Topography. Greece is in general a mountainous and rocky country. Timber areas are extremely scarce, although the country is drained by a large number of big and small rivers. Continental Greece (islands excluded) has an area of 51,000 square miles and is in "the dry-summer subtropics" region, thus having a fairly mild climate. She has a shore-line on three sides.

3. Nature of People. The 8,000,000 or so Greek people are in a majority quite alert, rather philosophical, educated, and industrious. Approximately 25 percent of them live in the capitol area of Athens and Piraens, because of political, industrial and other related reasons.

As a result most of the country's industry is developed in this area.

The difference between the population densities in the capitol area and the other provinces is illustrated in figure 1. This uneven population distribution has caused the establishment of expensive power plants in the heavily populated areas while the less expensive natural resources of the country are not developed because of their remote location.

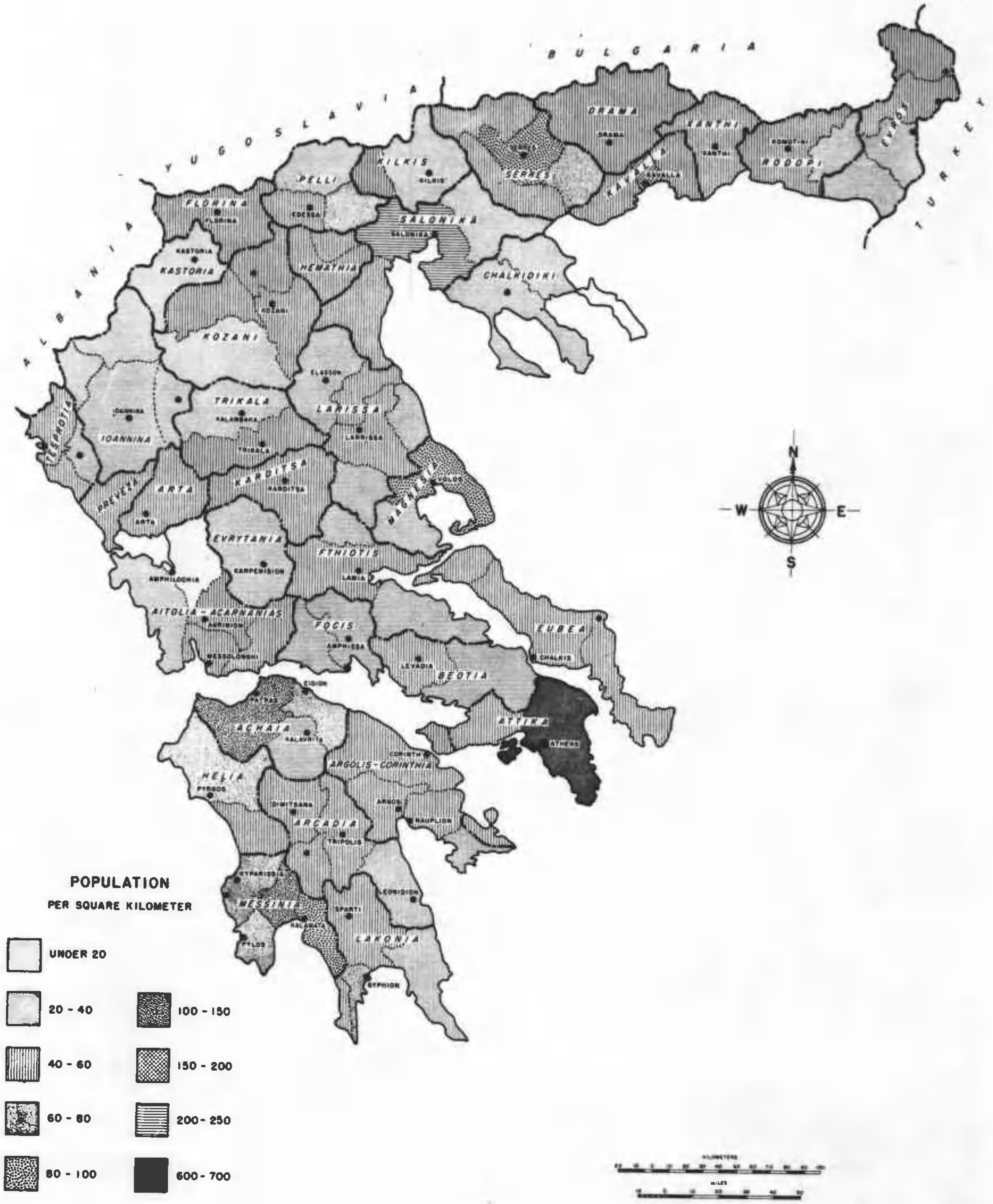

Figure 1. POPULATION DENSITY OF GREECE IN 1948 (4:12-13)

B. Resulting Situation

The factors discussed above lead to the following four conclusions:

1. Resources are limited. Those requiring small capital investment and simple exploitation have been used completely.

2. Insecurity does not encourage investment of private capital in the development of resources.

3. The country needs inexpensive energy and irrigation for agriculture.

4. A more even distribution of the population would be favorable to the most effective development of the resources.

C. Proposed Solution

One effective way to alleviate the above four conditions is to plan and organize a public power system which would draw the major part of its' power from the Greek rivers by means of hydroelectric plants. Thus, the undeveloped resources would be utilized; government financing could better accept the security risk; and irrigation and availability of energy would encourage a more favorable distribution of the people throughout the country.

SECTION II

SCOPE AND PURPOSE OF STUDY

A. Scope of Study

In this paper an analysis is made of the basic factors which have influenced the electric power supply in Greece based on available information and from personal experience and observation of the authors who are natives of that country and have lived there for twenty years. The paper is divided into two major parts: (1) The power development prior to the end of 1948 and, (2) the developments since 1948. Each part consists of a presentation of pertinent information and a correlated critical discussion.

B. Purpose of Study

Greece is now in a transition period as far as energy production is concerned. The primary purpose of this study is to assemble pertinent information and to critically survey the present nature, depth and breadth of this important change.

Another purpose is to help people of the United States understand the power problem in Greece and the means for solving it.

A final purpose of the study is to apply concepts, ideas and practices used in the United States, where power resources have been developed extensively, to the understanding and solving the power problem in Greece.

SECTION III

METHOD OF STUDY OF ELECTRIC POWER SUPPLY IN GREECE

A. Available Information

As a preliminary step to the study, all available literature pertaining to power supply in Greece or in areas having similar conditions to Greece was critically searched for information pertinent to this survey. The literature includes individual reports on different plants of the old and new power systems, minor information on the originally proposed units of the "New Power Program", and later reports on the progress of the projects as well as the accomplished changes. All this information was developed and correlated with the study. Detailed information was difficult to obtain since most of the projects are still under construction and no information is given as yet to the public. Therefore, most of it had to be obtained by time-consuming correspondence with the Public Power Corporation and the consulting groups. The major part of this study contains information on the projects as they were at the end of the year 1954. The reason for this is that most of the projects are not yet completed and final information is not available.

B. Factors Considered in Study

The foremost factors considered in this study were the possibilities and difficulties involved in providing Greece with an adequate modern electric power system. As a result, other benefits, e.g. navigation, irrigation, etc., which will be derived from this program were not presented.

Furthermore, since the immediate goal of the new system is to supply power to the mainland, the islands were completely omitted in the picture presented herein.

Finally, the study recognized that American and European practices were necessary in solving the power requirements problem in Greece.

SECTION IV

POWER SYSTEMS IN OPERATION IN 1948

The picture Greece presented power-wise in 1948 would classify her as a practically undeveloped power territory. The per capita production of electricity was less than 100 KWH per year for the entire area of the country and 160 KWH per year if only the areas that had some kind of electric service are considered. These figures are low compared not only to those of this country--which is 2,296 KWH per capita--but to those of any of the European countries. Italy, for instance, had 496 KWH per capita, figure 2.

Almost all of the existing power plants were of the thermal type and used imported oil for fuel. The few hydro-plants in existence were of little technical value, if any, their total capacity being around 9,000 KW.

All these plants, however were extremely inadequate. Age on one side, and their misuse during the Occupation Period (1941-1944) together with the destruction they suffered during the Second World War (1940-1941) and the Guerilla War (1944-1949) contributed to their gradual decay.

Furthermore, most of these plants were constructed, without consideration of the future, only to meet the largest possible percentage of the existing need. The

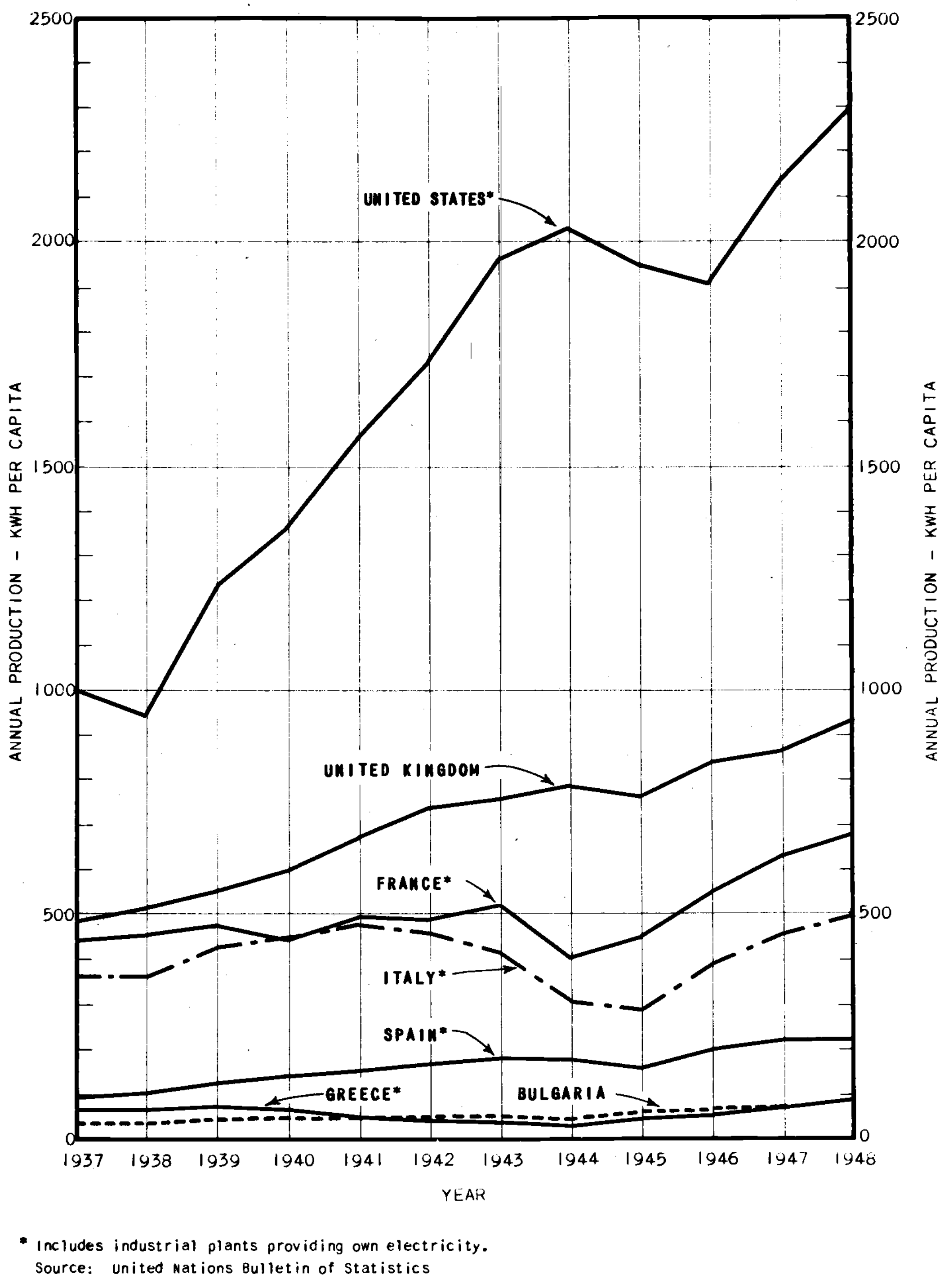

Figure 2. PRODUCTION OF ELECTRICITY, KILOWATT HOURS PER CAPITA (4:12-6)

following are the main reasons behind this way of thinking:

1. Lack of public or private capital.

2. Heavy taxes imposed by government on utilities.

3. Costly imported fuel and lack of capital for processing of raw Greek fuel.

4. High import duties.

5. Low load-factor operation.

6. Poor maintenance and lack of aggressive management.

The remainder of this chapter will show in detail the conditions existing in some of the heavily populated areas of Greece as well as in rural regions.

A. Major Systems

1. Capital Area. On October 14, 1925, an agreement was signed between the Greek Government, the "Syndicat d'Etudes et d'Enterpises" and the "Power and Traction Finance Company Ltd." of Queen's House, London terminating on December 31, 1985. According to this agreement the following rights were granted to the companies concerned:

1. To generate, transmit and distribute electricity for sale in an area of a radius of 12.4 miles having as a center Omonia Square in Athens.

2. To supply electricity outside of this

area upon agreement with any local authority, company or person.

This agreement granted to the above companies rights for the operation of street-car, bus and inter-urban railway operations, as well as special tax exemptions.

On March 21, 1931, the companies producing and distributing electricity under the agreement of October, 1925 were combined into the Athens Piraeus Electricity Company Ltd. (APECo.).

The Athens Piraeus Electricity Company Ltd. (APECo.) produces approximately 65 per cent of the total electric energy consumed in Greece, thus giving the advantage to the capital area, which includes the cities of Athens and Piraeus, of using 67 per cent of the total electric energy produced in the whole country. This enables the capital area to have an adequate electric service at reasonably low rates comparable to that available in the United States and most European countries. However, the existing generating capacity even in the capital area is not enough to take care of the continuously increasing demand. This increase is the result of the fact that the area under consideration is very heavily populated and is the industrial center of the country as mentioned in the preceding chapter.

Two generating stations are operated by A.P.E.Co.; one in St. George's Bay and the other at New Phaleron of a total generating capacity of 132,000 KW (at 1948). The energy generated is partly from steam-electric units and partly from Diesel-electric units. In both cases imported fuel is used.

The St. George's Bay plant was using British coal until the beginning of the war in 1940. During the war, because of the fact that no other fuel was available or imported, Greek lignite was used.

The New Phaleron generating plant was completed after the war in an effort to keep up with the continuously increasing load and as a result of that is the more efficient of the two plants using Diesel units.

The generated power from these two plants is transmitted with overhead and underground 22 KV transmission lines throughout the Attica Peninsula. This voltage is stepped down to 6.6 KV for primary distribution. The secondary service is at 220/380 3-phase 4-wire of a frequency of fifty cycles which is the frequency of the system throughout the whole country, and conforms with European practice.

The above mentioned company is the only one operating in the capital area, except for small generating units privately operated by industrial plants for their own needs. Because of the high customer density, the tax exemption and franchise rights granted through the agreement with the government, the investment of foreign capital and the good management has succeeded in providing the area served with effective, in comparison with the rest of the country, service and rates.

2. Salonika. The second major power company is located in the northern part of the country in the city of Salonika, second largest city in Greece.

In 1892, electric service was established in Salonika by the "Compagnie des Tramways et d'Eclairage Electrique de Salonique" under Turkish laws. Since 1940, this company, under the name of Salonika Tramways and Electric Co., has been under the control of the Greek Government.

The S.T. & E. Co. operates three stationary and two floating Diesel-electric generating stations having a total rated capacity of approximately 22,500 KW of direct current. This figure does not include the small amount of a-c power provided by privately-owned companies adjacent Neapolis and Calamaria. There are around 440 miles of 220/440 volt direct-current distribution lines owned by the S.T. & E. Co.

The system, like most of the systems existing in Greece is quite inadequate for the continuously growing city of Salonika.

3. Hellenic Electric Company. The Hellenic Electric Company is the third in size electric utility enterprise having an installed capacity of about

9,000 KW.

The National Bank of Greece is the principal shareholder of the H.E. Co. which serves the cities of Ioannina, Pyrgos, Kalamata, Tripolis, Argos-Nauplion, Loutraki and Katerini on the mainland of Greece, Chalkis and Edipsos on Euboea Island, Argostoli on Cephalonia Island and Zakynthos on Zakynthos Island.

4. Patras. Patras is the third largest city in Greece and as a result has above average electric utility facilities as compared to the facilities provided in most areas of the country. The city together with the surrounding area of Northern Peloponnesus is served by the "Greek Hydroelectric Company of Patras". This company is partly owned by the city of Patras (forty-one per cent of stock) and partly by the National Bank of Greece (fifty-nine per cent). It has been granted a franchise expiring in 1959.

The company owns and operates a hydroelectric station of 2400 KW capability and a Diesel-electric station of 3,741 KW capability, or a total of 6,141 KW.

Power is distributed over thirty-three miles of 8800-volt primary lines and seventy-seven miles of 127/220-volt secondary lines.

5. Volos. The city of Volos and the adjacent areas are supplied with electric energy by the Electric Company of Volos. This company was established in 1911 and the initial plant was for a direct-current system.

In 1927, the existing plant was converted to an alternating-current system which has been government controlled since 1940.

The Electric Company of Volos has a Diesel-electric generating station having a capacity of about 1,925 KW. The distribution system is composed of ninety-five miles of line. The primary service is at 6,600 volts and the secondary service at 127/220 volts.

The above company serves about 12,000 customers, or eighty-five per cent of the total possible customers of the area served, which is a fairly high score in comparison to the other companies in existence in Greece.

B. Minor Systems

Besides the five major electric utility operations already mentioned, there are approximately 175 other minor systems throughout the mainland of Greece.

A few general facts applying to the majority of these operations as well as the part they constitute in the general picture is given below.

The information in table 1 shows that the provinces of Greece are served by plants having an aggregate installed capacity of 20,000 KW a-c and 8,000 KW d-c or a total of 28,000 KW. This constitutes approximately fourteen per cent of the total capacity installed in Greece. These systems are small and vary in size from a few kilowatts to approximately 2,000 KW. Most of these plants are small Diesel-electric units. There are, however, a few hydro-electric plants at Verria, Naoussa, Edessa and Serres.

Each one of these systems is independent of the other both financially and physically. As a result, they suffer the problems present in any small operation. One-third of the capacity is d-c as shown in table 1.

Finally there are two important characteristics for most of these systems: (1) provision of service only from sunset to sunrise, and (2) little or no apprecia-tion to the need for maintainance resulting in unreliable service.

Table 1

SYSTEM INSTALLED CAPACITY-KW

Current	Major Systems	Minor Systems	Total
a-c	154,000	20,000	174,000
d-c	23,000	8,000	31,000
Total	177,000	28,000	205,000

A complete picture of the systems in Greece may be seen in the figures of table 2 where the rated a-c and d-c capacities together with the corresponding maximum recorded demands in each Greek Province have been included. This table presents information assembled from many sources. Wherever the information was contra-dictory, the minimum existing capacity and maximum of the given demands were chosen for the computation of the results.

Table 2

EXISTING POWER SYSTEMS BY PROVINCES IN 1948

Province	Area Square Miles (13:1-2)	Population (13:1-2)	Rated Capacity KW a-c	Rated Capacity KW d-c	Maximum Demand KW a-c	Maximum Demand KW d-c	Installed Capacity in Watts per Capita	Total Max. Demand in Watts per Capita
Achaia	1,163.6	228,871	7,969	56	4,360	10	35.06	19.09
Aitolia-Acarnania	2,204.8	220,138	875	316	607	165	5.41	3.51
Arcadia	1,680.7	154,361	776	70	450	40	5.48	3.17
Argolis-Corinthia	1,753.5	198,747	3,170	175	1,521	180	16.83	8.56
Arta	672.2	72,717	0	361	0	225	4.96	3.09
Attica	1,469.3	1,556,029	137,850	755	85,155	518	89.10	55.06
Beotia	1,210.4	106,838	425	420	272	226	7.91	4.66
Chalkidiki	1,153.7	75,735	134	169	74	119	4.00	2.55
Drama	1,352.0	120,492	*	869	14	669	7.21	5.69
Elia	1,152.9	188,274	738	24	405	20	4.05	2.26
Euboea	1,551.8	164,542	1,352	536	644	294	11.47	5.70
Errytania	786.2	39,678	*	*	*	*	*	*
Evros	1,640.5	141,340	168	692	138	341	6.08	3.39
Florina	722.3	69,391	430	0	308	0	6.20	4.44
Focis	802.2	51,472	151	125	86	82	5.36	3.26
Fthiotis	1,619.8	148,322	92	1,041	50	722	7.60	5.20
Hemathia	651.8	96,439	1,845	0	320	0	8.76	3.32
Ioannina	1,954.9	153,748	1,155	0	610	0	7.51	3.97
Karditsa	969.3	138,786	426	0	300	0	3.07	2.16
Kastoria	648.6	46,407	327	20	185	16	7.48	4.33
Kavala	837.5	136,337	1,716	0	1,055	0	7.59	7.74
Kilkis	1,009.1	89,475	200	0	140	0	2.23	1.56
Kozani	2,265.7	177,838	534	0	354	0	3.00	1.99
Lakonia	1,453.2	130,898	275	0	180	0	2.10	1.37
Larissa	2,170.1	208,120	1,880	0	1,130	0	9.03	5.43
Magnessia	979.1	153,808	1,925	163	1,150	63	6.57	7.89
Messinia	1,118.8	227,871	1,535	603	777	211	9.38	4.33
Pellis	1,006.2	116,969	235	650	225	475	7.57	5.98
Preveza	374.5	56.779	0	431	0	172	7.59	3.03
Rodopi	998.3	105,723	0	550	0	300	5.24	2.84
Salonika	1,326.2	459,856	5,970	22,612	1,252	6,595	62.14	8.36
Serres	1,564.5	222,549	1,160	*	480	40	5.21	2.34
Thesprotia	570.8	47,299	0	53	0	49	1.12	1.04
Tricala	1,280.7	128,227	465	0	360	0	3.63	2.81
Xanthi	675.9	89,891	718	0	392	0	7.99	4.36
Total			174,496	30,691	102,994	11,532		
Grand Total	42,791.1	6,324,067	205,187		114,526		32.44	18.11

* Information not available

SECTION V

POWER PROBLEMS IN EXISTENCE IN 1948

A question which is probably by now in the reader's mind after having read the previous chapters is: "Why has the use of electricity in Greece been restricted between so narrow margins?"

The limited use of electricity results indirectly from the history and topography of the country already discussed, and directly from a few factors related to the general situation. A consideration of these factors is essential in understanding the planning and operation of the "New Electric Power Program" discussed in the following chapter.

A. Factors Limiting Use of Electricity

One of the main factors limiting the use of electricity was the fact that in numerous localities the generating equipment had been inadequately maintained so that it could not produce rated output. As a result, the companies serving the above localities had placed restrictions upon present users and refused service to any new customers. The picture becomes even darker if the difficulty of obtaining generating and distributing equipment is included. Consequently, numerous towns and villages had never had electric service.

Another factor, which has been witnessed by the authors in many towns, is that they were supplied with electricity only because there was a small factory which distributed it as a by-product to its principal function. This, of course, could not be done at the expense of that function--in other words, not during most of the working hours, This was the main reason for which some of the villages did not have electricity in the daytime, as mentioned in the previous chapter.

In spite of the disadvantage of not having service available twenty-four hours a day, the above scheme of supplying electricity would have been fairly satisfactory, were these factories distributed more favorably in the country. This was not the case, however, as it can be seen in table 3; although three-fourths of the population lived in the country outside the capital area, the amount of power consumed by these people was smaller even than that used only for lighting in Athens, the latter being less than fifty per cent of the total consumption in the capital area.

Furthermore, the concessions for operating electrical facilities were for various lengths of time. As a result, it was extremely hard to find new capital for investment in the electric utilities. On the other hand, those who had already invested were not willing to

Table 3 (4:12-5)

USE OF ELECTRICITY IN 1948

Capital Area	1,000 KWH	% of Total
Lighting	145,693	45.6
Power	173,679	54.4
Total	319,372	100.0
Other Systems		
Lighting	30,960	61.4
Power	19,442	38.6
Total	50,402	100.0

promote the business aggressively because of the temporary nature of the concessions.

Besides the above factors, there are a few strictly financial reasons that have, in the past, limited the use of electricity in Greece. For instance, a main factor, which in most cases is not even considered in this country, is that the income of most of the people is so low that only a minimum amount of electrie power can be purchased. This and the fact that, with the exception of the capital area, the price of electricity was high (see table 4), constitute the two direct factors that made people reluctant to use electric power. Furthermore, appliances, motors and other utilization equipment were expensive and difficult to get because of high duties and taxes, import limitations and restrictions on the amounts of foreign exchange available to the nation. The high price of electricity outside the

Table 4 (4:10-5)

ELECTRIC POWER RATES IN DECEMBER 1948

Loads	Cents Equivalent per Kilowatt Hour Capital Area	Average of Salonika Volos and Patras
Private lighting	3.7	11.4
Power	1.6	5.3
Public buildings	2.2	10.1
Street lighting	2.0	6.0
Average	2.4	8.2

capital area to a large extent results from the taxes included in the electric bills paid by the consumers which, as seen in table 5, were extremely high. Compare the five per cent tax of the capital, to the thirty-three per cent of Salonika, or to the fifty-three per cent of Veria. Lack of uniformity in these taxes is another factor that has caused many complaints.

B. <u>Effects of Existing Situation</u>

From the subject matter discussed this far, the condition of Greece powerwise in 1948 may be best described by the following five points:

1. The lack of electric energy was so severe that the industry of the country was extremely limited. Furthermore, expansion of production was prevented. For these reasons the supply of manufactured goods was insufficient for even the most essential needs of the nation. Note that the per capita electric power

Table 5 (4:12-8)

MONTHLY PERCENTAGE TAX PAID BY "PRIVATE LIGHTING" CONSUMERS 1948

City	Government %	Municipal Government %	Payment of Bank Loans %	Total Taxes %
Agrinion	16	8		24
Athens	5			5
Chalkis	16			16
Corinth	16	30		45
Drama	16	10	15	31
Edessa	16	10		26
Ioannina	16	10	15	41
Kalamata	16		15	31
Kavalla	16		15	31
Komotini	16	10	15	41
Kozani	16		15	31
Lamia	16	6	15	37
Larissa	16		15	31
Levadia	16	20	15	51
Nauplion	16	10	15	41
Patras	16	4	15	35
Salonica	16		7	33 *
Thebes	16	10	15	41
Trikala	16	10	15	41
Tripolis	16		15	31
Veria	16	12	25	53
Volos	16	10	15	41
Xanthi	16		15	31

* A ten per cent pension fund tax is included in the total tax.

production per year was less than 100 kwh, until 1950.

2. The use of electric energy was inequitably divided in the various areas of the country. This, however, does not mean that wherever it was available it covered all the needs of that area.

3. In her effort to develop more power facilities Greece had to export great sums of money in order to

obtain fuel for the operation of the existing plants. On the other hand, the available potential energy in the rivers and poorer-quality lignite mines was undeveloped for reasons already mentioned. The combination of these two shows that the electric power requirements of the industry as well as the most essential needs of the people were dependent upon availability of imported energy.

4. The cost of electricity was quite different in different areas of the country, in some areas being beyond access to the average Greek. The high price, however, did not protect the users from inconveniences and financial losses from frequent failures caused by poor maintenance of the electrical supply facilities.

5. The existing situation in 1948 offered no prospect for construction of any plants to meet the continuously growing needs of the country.

SECTION VI

NEW ELECTRIC POWER PROGRAM

From the data and the accompanying discussion presented in the previous shapters, it is apparent that a technical change was imperative for the advancement of Greek economy. This advancement should effectively satisfy the most important need, namely, the increase in demand for manufactured products.

The above situation was fully realized by the Greek Government early in 1948 when the country was still recovering from the recent wars. It was realized, furthermore, that this situation could be best met by the utilization of potentially available energy in the country and by their transformation into electric energy for most effective use. This, of course, presumed an expansion of the existing electric systems. Increasing the utilization of electricity involved many adverse factors, but there were certain favorable conditions.

A. General Conditions Favorable to System Improvement

In general, the most important of the favorable conditions for electric expansion in Greece may be summarized as follows:

1. The apparent desire of consumers to avail themselves of more of the advantages of electricity.

This was proved by the fact that appliances imported or manufactured in Greece at moderate prices were bought as fast as they could be made available.

2. There was a serious need to exploit new thermal-energy resources, since the importation of natural gas, petroleum, and high-grade solid fuels was found uneconomical; no attempts have been made to find these fuels locally.

3. The post-war trend toward modernization and mechanization of industry. Particularly in those fields where Greece possessed the raw materials, but was obliged to export them for manufacture because of inadequate and obsolete factories.

4. The essential need for refrigeration for food preservation. This would improve the economy of the country since products could be distributed and consumed throughout the land and not at the production location as has been necessary in the past.

5. The scarcity and consequent high price of convenient fuels for cooking. Generally, electric cooking in Greece was almost non-existent. Even in the capital area, where rates are quite high relative to income, twenty-nine families out of 100 used electric power for cooking, which indicates a strong preference for electricity for cooking.

6. The recognized need to develop more of the mineral resources and improve agricultural production.

B. <u>Financial Factors Favorable to System Improvement</u>

The above conditions, favorable as they may be, would have been of little or no help and the expansion effort would have remained in the theoretical stage, were there no capital available. However, the presence of certain financial factors at the time facilitated and encouraged the new program. These factors are in brief the following:

1. The Marshall Plan, implemented through the Economic Cooperation Administration (ECA), now Mutual Security Agency (MSA) rendering assistance to all countries in the program requiring aid in building up their power supply.

2. The Greek-Italian War Reparations Agreement contributing the equivalent of funds for a large proportion of the requirements.

3. The re-establishment of trade and promotion of cooperation between the countries of Europe by ECA, contributing indirectly to the program.

4. The end of the guerrilla war permitting the nation to contribute more funds for non-military purposes.

5. The abundance of labor supply because of

discharged military personnel at the end of the war.

Statistics of the percentages contributed by the various sources for the new program may be found in table 6.

Table 6

PROPORTIONAL CONTRIBUTION OF VARIOUS FINANCING SOURCES TO THE NEW POWER PROGRAM

Greek Drachmae	42.3%
Italian Reparations and Greek-Italian Trade	32.4%
Indirect Inter-European Contributions	13.6%
Marshall Plan (USA)	11.7%
Total	100 %

C. Outline of the "Electric Power Program"

At the end of 1948, the Greek Government included in its four-year Economic Recovery Program, the utilization of the potential energy of several rivers as well as those of lignite deposits and their transformation into electric energy. A state-owned corporate body, known as the Public Power Corporation, was established by the Greek Government, which had the responsibility of developing and operating a new nation-wide electric power system.

In turn, the Public Power Corporation, engaged Ebasco Services Incorporated of New York, to manage and direct: (1) the development and operation of the nation-wide electric power system, (2) the development of the projects constituting this system and, (3) the business and operation of the Public Power Corporation under the supervision of its Board of Directors.

These two corporations studied jointly the situation and developed a program. This program, however, has been altered repeatedly and, therefore, will not be discussed. A general picture of the program is indicated by table 7. Wherever the projects have been completed the actual size and cost are stated; wherever they are under construction or in the design stage only estimates can be included as of December, 1954. It is this program in its final form, that will be presented in detail in the following pages and to which comments and suggestions will be directed.

1. Generation. The final study performed by the previously mentioned consulting groups arrived to the conclusion that according to (a) the general trend in power demand and, (b) the available capital, Greece would need in the immediate future capacity in the order of 500 megawatts in addition to the existing facilities. Furthermore, it was decided that this requirement could be best met by the construction of seven generating plants, five hydroelectric and two thermal having an aggregate capacity of 520 megawatts. A description of these plants follows below:

Table 7

COST OF THE NEW ELECTRIC POWER SYSTEM

Project	Size, KW	Cost, $
A. Production		
*Agra Hydroelectric	40,000	16,600,000
Ladhon "	55,000	22,100,000
*Louros "	5,000	4,500,000
Kremasta "	180,000	51,500,000
Megdovas "	80,000	11,600,000
*Aliveri Thermal	80,000	15,700,000
Ptolemais "	80,000	15,000,000
Totals	520,000	177,000,000
B. Transmission		
150 KV Lines and Substations		34,000,000
C. Distribution		
15 KV Circuits		24,000,000
D. Miscellaneous		
Administration Cost		17,000,000
Irrigation		4,000,000
General Plant		2,400,000
Other		1,600,000
Total		25,000,000
Grand Total		260,000,000

* Completed projects. Other projects under construction or being designed.

a. Agra Hydroelectric Project. The Agra hydroelectric project was constructed under the direction and supervision of "Ebasco Services Inc." and started operating June, 1954.

The total fall of approximately 520 feet between Lake Agra and the generating plant was utilized by means of a dam and an underground tunnel approximately 1.03 miles long. The water carried by the tunnel is fed into two water-wheel generators of a capacity of 20,000 KW each. The tailwater is discharged into a small local drainage channel which is used as a reservoir.

The Agra project is shown in figure 3 as it was on May 4, 1953. The powerhouse and the penstock can be seen under construction.

The energy produced by this generating plant (40,000 KW) is at 15 KV and is stepped up to 150 KV for transmission.

The Agra project cost about $16,626,000 and, for the time being, generates enough power to take care of the needs of Macedonia and Thrace. However, an interconnection with the Aliveri thermal project is expected later in order to meet the increasing demand of the above area.

b. Ladhon Hydroelectric Project. This dam is constructed close to the village of Spathari on the Ladhon River which drains a surface area of 430 square miles in the north-central highlands of the Peloponnesos. The project utilizes the fall of the river between the Pidima Bridge and the Spathari Bridge, and comprises: (1) an arch dam approximately 115 feet high located in the canyon above the Pidima Bridge and, (2) a low-pressure tunnel, approximately 5.4 miles long, surge tank, vertical shaft, and steel penstocks, (3) a power plant with an installation of two 27,500 KW, reaction type, hydroelectric units operating under a gross head

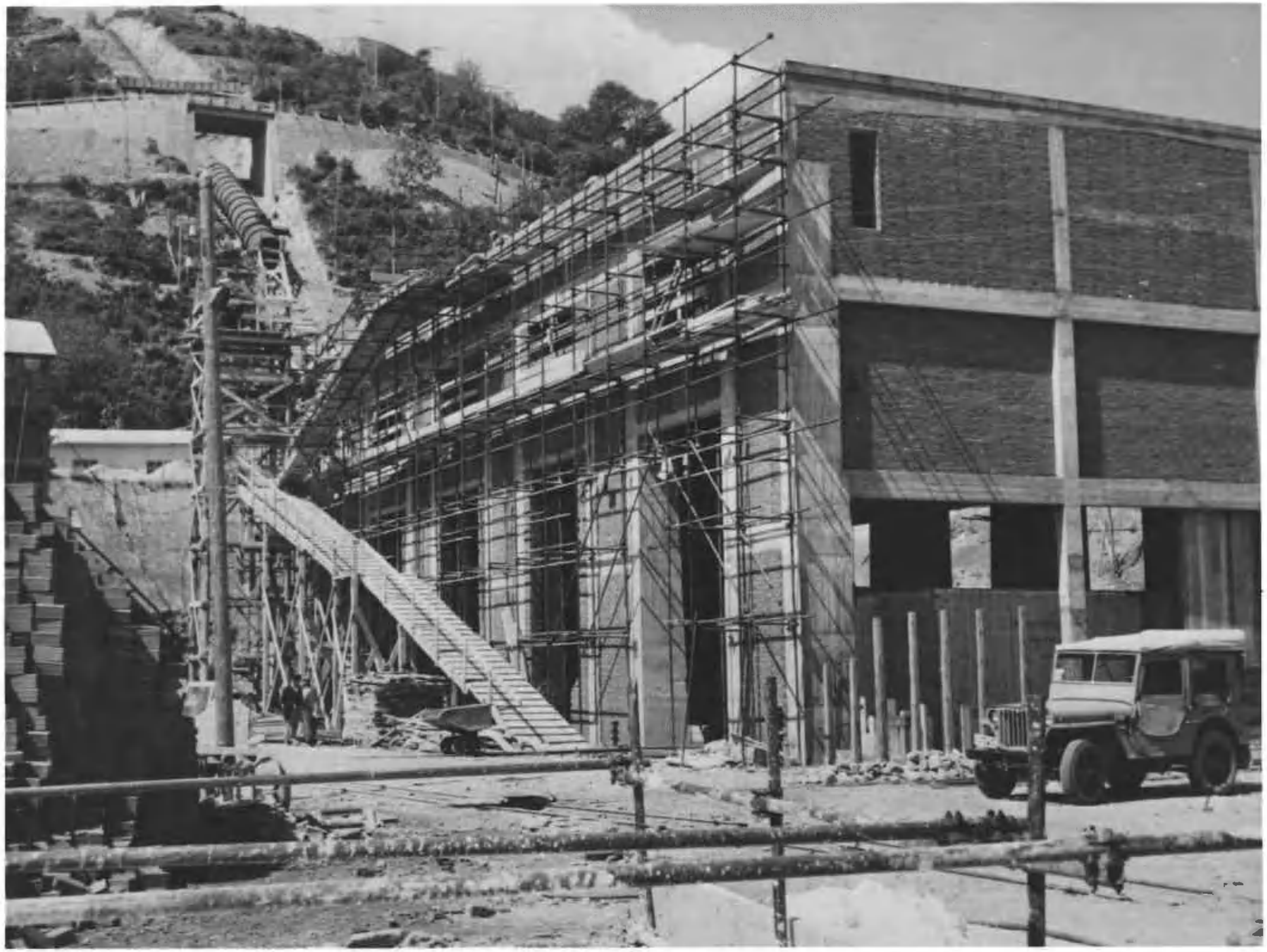

Figure 3. AGRA HYDROELECTRIC PROJECT
Powerhouse south penstock erection in progress in background. Date: May 4, 1953

of approximately 722 feet, each producing power at 15,000 volts and each connected through step-up transformers to the 150 KV transmission network, (4) a tailrace tunnel approximately 0.6 miles long discharging into the river at a point a short distance above the Spathari Bridge.

In general, the Ladhon generating station is a run-of-stream plant with sufficient pondage for weekly regulation. The pondage behind the dam is sufficient to permit operation at an estimated twenty per cent load factor during periods of low stream flow.

Figure 4 shows the powerhouse and penstock under construction as seen from the Spathari Bridge.

c. Louros Hydroelectric Project. The Louros project will be discussed in more detail than the previously presented projects since it has certain interesting differences as it may be seen below:

(i) The Louros River. The Louros River originates in Epirus near the Albanian border and flows in a southerly direction to Salaora Bay. Between the headwaters and Kalogirou Bridge, the river drains a mountainous and barren area. Below Kalogirou Bridge, the river enters the Arta Plain, the elevation of which is close to sea level.

An important characteristic of the Louros River is that its' total flow is large in relation to its' small surface drainage area, because of contributions from

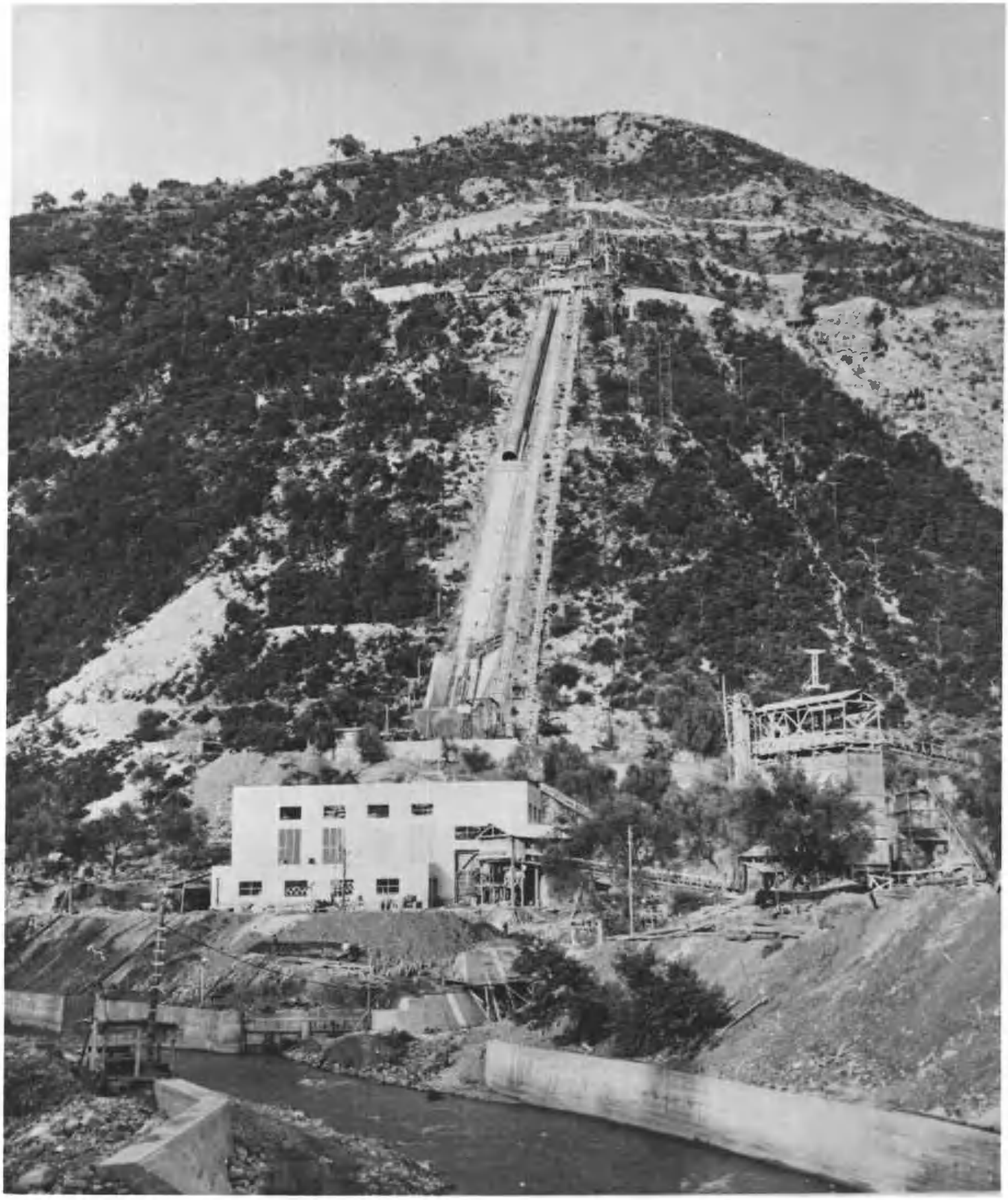

Figure 4. LADHON HYDROELECTRIC PROJECT
Powerhouse and penstock seen from Spathari
Bridge. Date: October 14, 1953

springs along its' length. The most important of these, St. George's Springs, contributes from thirty-five to sixty-four per cent of the total flow of the river at that point. Due to the relatively large contributions of water made by the various springs, the flows of the Louros River exhibit variations which are remarkably small.

(ii) Potential Hydroelectric Developments. The only site that appeared feasible for a dam is located in the reach between St. George's Springs and the Arta Plain. The area that was to be served from this plant is a part of the northwestern corner of Greece conceded by many to be one of the poorer parts of the country.

Two alternative plans of development were studied: That of constructing a high dam and that of a low dam.

(iii) Adopted Program. After considerable discussion between the Greek Government and the consulting groups, the low dam plan was adopted. Construction started on June, 1951 and was essentially completed during March, 1954 when the amount spent on the project was $4,523,000. The entire project comprises:

(a) A diversion dam approximately 360 feet long and fifty-two feet high with no gates or other means of control.

(b) A simple intake and a canal equipped with racks and tainter gates. From the canal water flows through a tunnel and open canal and flume sections to a headworks, then to the plant by means of a single penstock branching to supply the two units.

(c) The power plant contains two 2500 KW, reaction-type, hydroelectric units, connected to a 15 KV distribution bus.

At the present, the plant serves an isolated power system consisting of 15 KV primary distribution lines serving the cities of Ioannina, Preveza and Arta, plus numerous adjacent villages.

d. Kremasta Hydroelectric Project. As of December, 1954 the construction of this station had not yet started for legal differences between the Greek Government and a company, which, in 1940 was granted the rights of the river but as of today has made no move for its utilization. As soon as this matter is settled construction of the project presented below will begin.

The Kremasta dam will be located on the Acheloos River in a narrow gorge some 3,130 feet below the point where the Agraphiotis and Megdova Rivers enter the Acheloos. The proposed project comprises:

(i) A concrete or rock-fill dam approximately 370 feet high, located in the canyon at the Kremasta site, creating a reservoir with a water storage of 700,000 acre feet.

(ii) A diversion tunnel approximately 2,620 feet long and forty-nine feet in diameter which, after the construction period, will be used as a tailrace tunnel.

(iii) An underground power plant with an installation of three 60,000 KW reaction-type turbines, operating under a gross head of approximately 288 feet, each connected through 15/150 KV transformers to the 150 KV transmission network.

It is anticipated that the construction of the project will take approximately seven years.

e. <u>Megdovas</u> <u>Hydroelectric</u> <u>Project</u>. This project was just recently introduced into the program of the Public Power Corporation. As a result, the available information is extremely limited (18:122). Here are, however, the fundamental characteristics of this project:

The dam will be located on the Megdovas River, approximately half way between Lamia and Karditsa in central Greece. The proposed project comprises:

(i) A concrete or rock-fill dam approximately 160 feet high, located above the point where the Megdovas and Kastritsiotis Rivers meet. The flow of the latter will be diverted into the reservoir created behind the dam, the storage of which will be about 170,000 acre-feet.

(ii) A diversion tunnel approximately 560 feet long and 8.2 feet in diameter.

(iii) An underground power plant with an installation of two 40,000 KW reaction-type turbines, operating under a gross head of approximately 1700 feet, each connected through 15/150 KV transformers to the 150 KV network.

It is anticipated that the construction of the project will take approximately four years. However, the beginning of the construction has not been scheduled yet.

f. Aliveri Thermal Project. This station is located on the Karavos Gulf of Euboea Island close to the village of Aliveri. It consists of two 40,000 KW hydrogen-cooled generators, each one connected to two pulverized-lignite-fired steam-generating units, each rated 90,000 kilograms of steam per hour at a pressure of sixty-five kilograms per square centimeter 485° C. It is estimated that the above plant will require 750,000 tons of pulverized lignite per year for full output.

Euboean Gulf water is used directly for condensing service, and in heat exchangers to cool service water for oil coolers, bearings and generator hydrogen coolers. Intake and discharge structure is arranged so that flow reversal can be accomplished to remove troublesome marine growths from the intake piping that extends into the Gulf.

Steam-generating units are designed to burn "pulverized Greek lignite" as primary fuel with fuel oil as secondary or standby fuel. Lignite can be received by water or rail, and yard storage and handling facilities are provided. Fuel oil is received by water, and storage facilities are provided. Crushing, drying and pulverizing equipment is designed to utilize Greek lignite or imported coal. Flue dust separators and ash-removal equipment are provided.

The station is laid out so that future enlargement can be effected if and when required.

Electric energy is produced at the 15 KV level, then transformed to 150 KV by means of two transformers and fed into the 150 KV transmission circuit. Part of the energy is taken off the distribution panel of the substation for direct distribution to the neighboring area at the 15 KV level.

Figures 5 and 6, respectively, show the reinforced-concrete structure of the powerhouse and the electrical control room. The structure of the powerhouse was designed to utilize a minimum of structural steel, which is extremely expensive in Greece, but to withstand earthquake shocks, which are rather frequent in that area.

The Aliveri Station was the first of the new plants

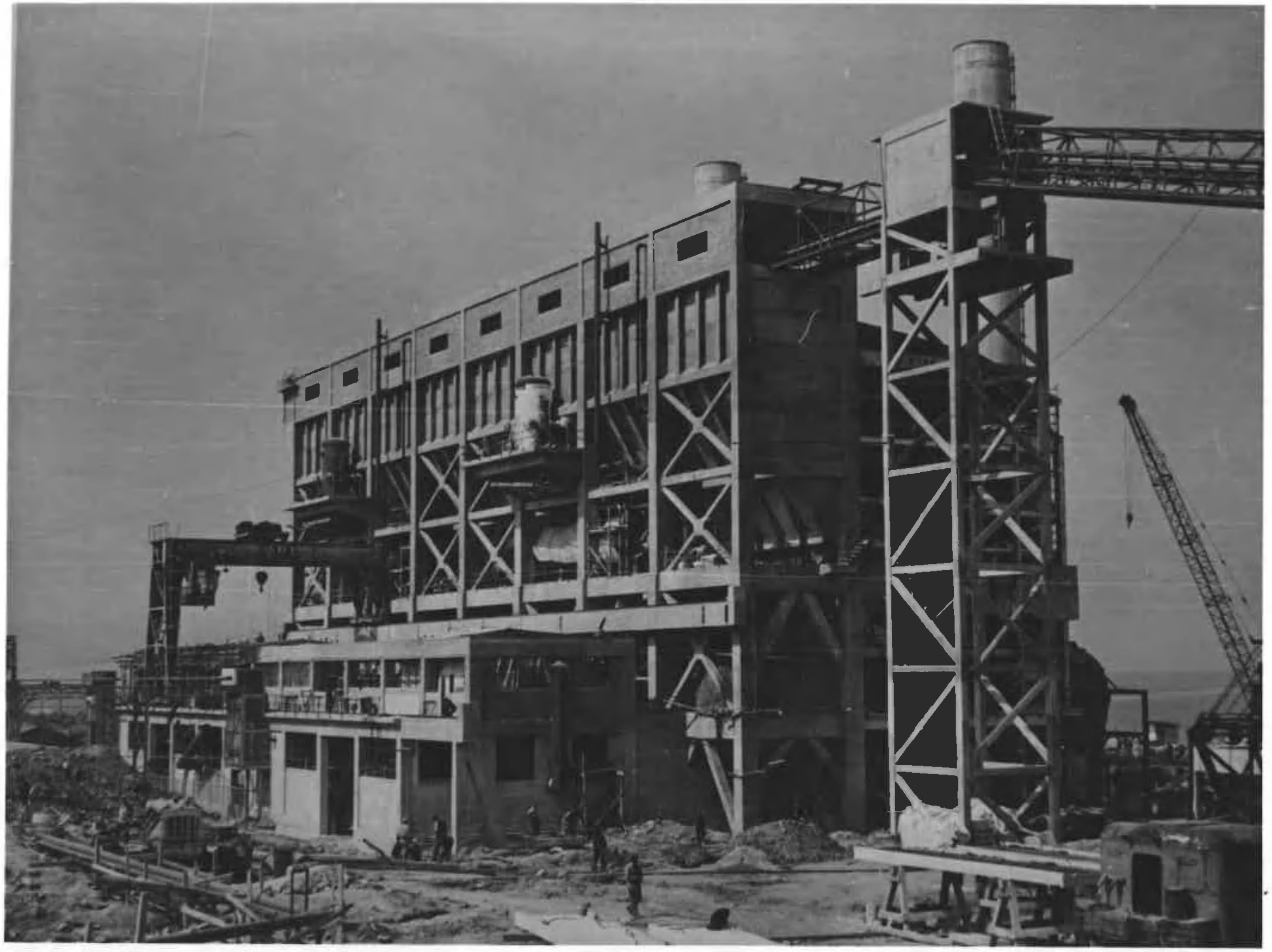

Figure 5. ALIVERI THERMAL PROJECT
General view of powerhouse looking southwest
Date: April 4, 1953

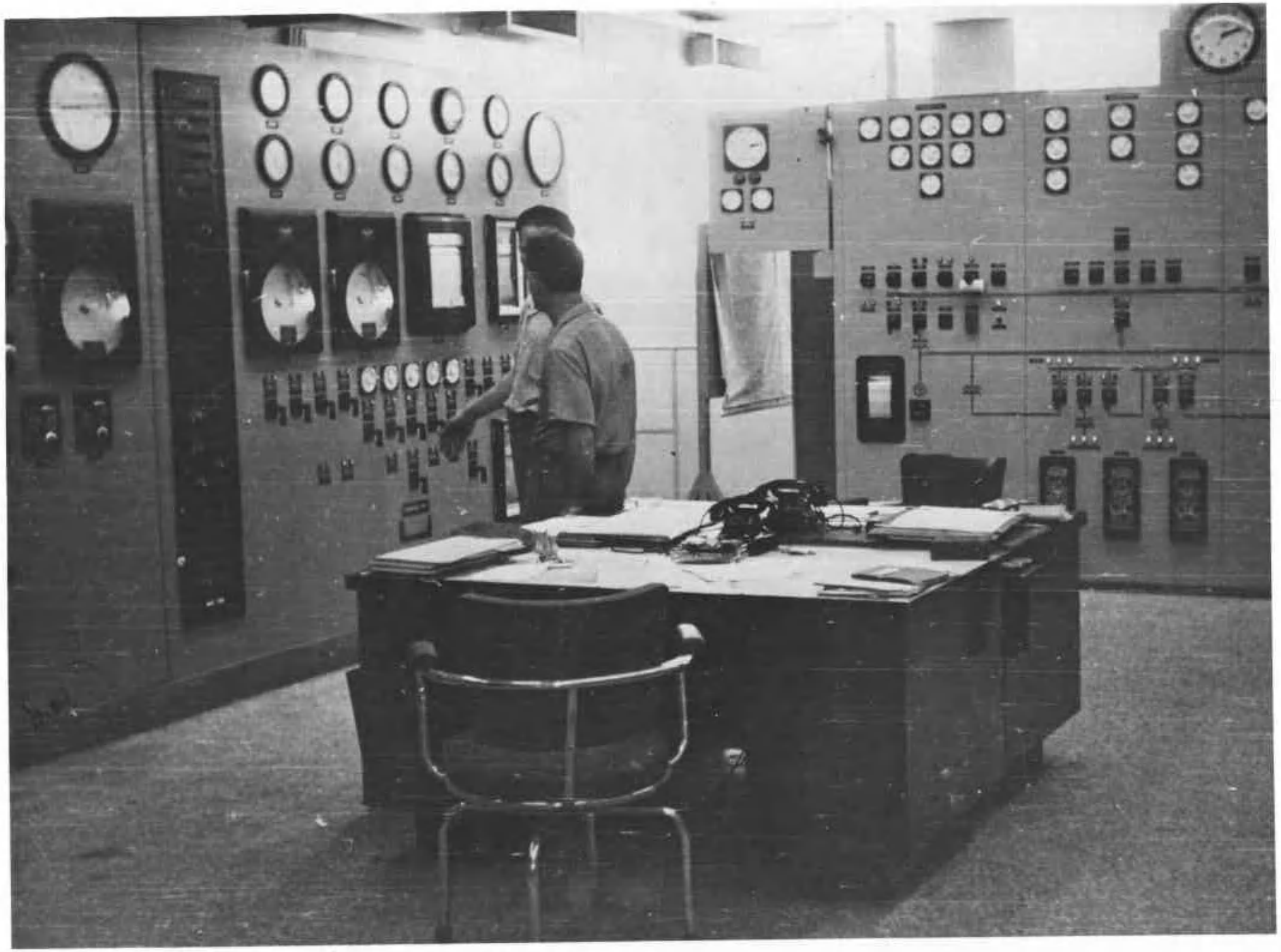

Figure 6. ALIVERI THERMAL PROJECT
Control room. Main control board in right. Turbine No. 1 control board in left. Date: April 9, 1953

constructed by the Public Power Corporation. Construction started late in 1951, the first unit was put into operation in July, 1953 and the project was completed December, 1954. The cost of the project was $15,700,000.

g. Ptolemais Thermal Project. This is the last of the projects which are still in the planning stage, the delay resulting from the fact that the construction of the station should be accompanied by the development of a lignite mine in that area. This project will be located at Northern Greece.

Originally (beginning of 1951) it was planned that this station needed one 40,000 KW generator. However, the demand has increased since then and, as of April, 1955, an 80,000 kilowatts plant was under consideration.

It is estimated that the Ptolemais Station will require approximately 1,300,000 tons of lignite per year.

It is estimated that the construction of this project will take approximately three years and that the cost will be about $15,000,000.

2. Transmission.

a. General. A transmission system to operate in conjunction with the already presented power plants has been proposed and is under construction at the present time in Greece. The new system uses a single voltage of a nominal value of 150 KV. This selection was made after consideration of the present and future requirements of the country as a whole. The 150 KV level was determined to be the simplest, most economical, and most efficient in meeting these requirements. Furthermore, it is a widely used standard European voltage.

This single voltage of 150 KV is high enough to deliver power economically from the Kremasta Hydro-electric Station to the load, (about 150 miles) and low enough to provide economical coverage of Greece with transmission lines. The capability of the lines is such that heavy-power-consuming industries may be located any-where on the system.

The area served from this system is shown in figure 7. It will be noticed that the present system does not extend into eastern Thrace, northern Epirus, and southeastern Peloponnesos, the reason being that the load forecasts of these areas are extremely low. The system, however, is capable of future extension into these areas.

b. Transmission Lines. The power produced by the generators is taken into step-up transformers. Each transformer feeds an 150 KV switchyard bay, which in turn, is connected to the 150 KV bus through oil circuit-breakers and gang-operated disconnecting switches. A typical switchyard bay may be seen in figure 8.

The network under construction uses single-circuit 150 KV lines without any provision for a second circuit

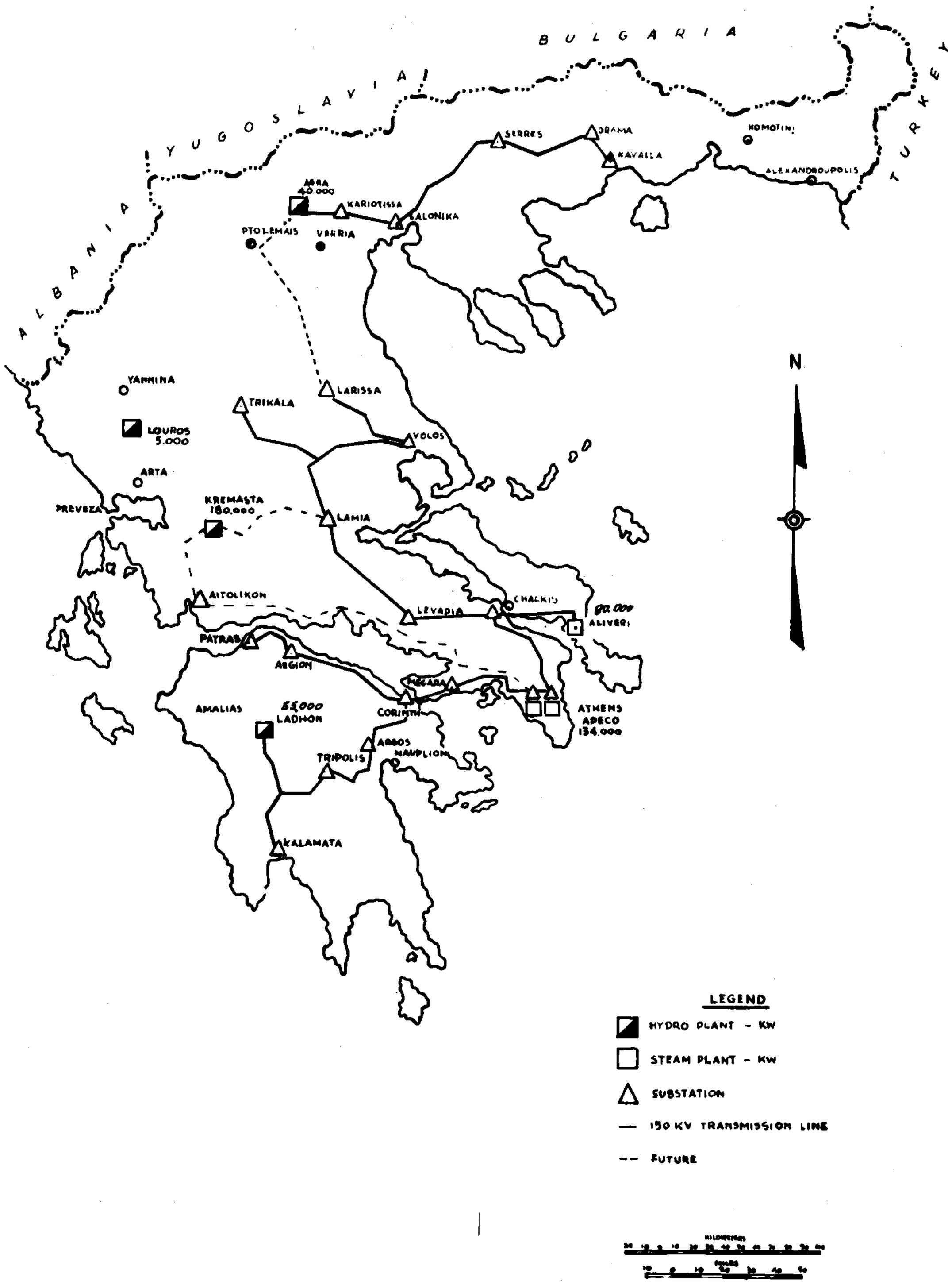

Figure 7. GENERATING STATION, TRANSMISSION LINES AND SUBSTATION LOCATIONS

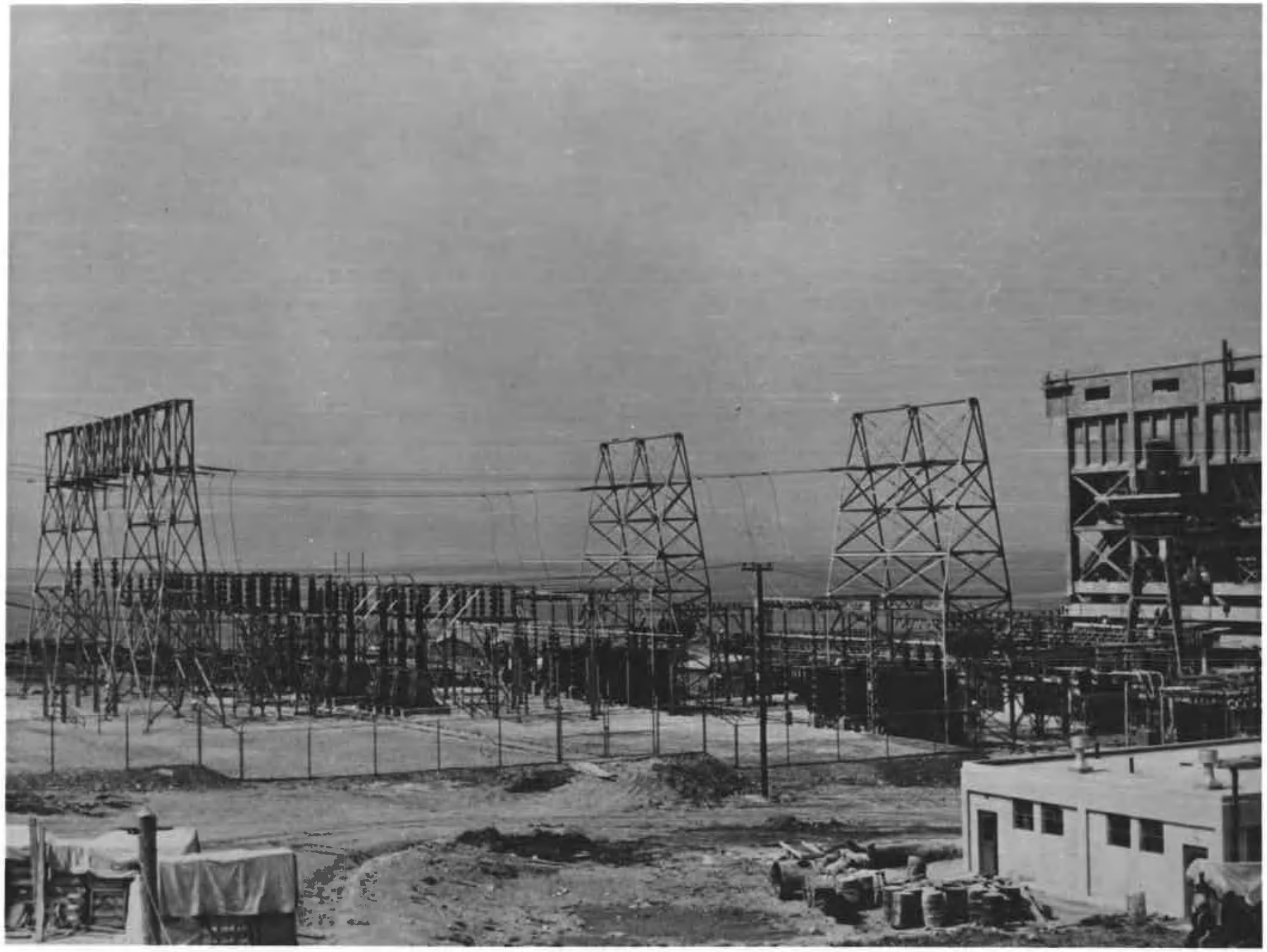

Figure 8. ALIVERI THERMAL PROJECT
General view of switchyard looking southwest
Date: April 21, 1953

on any of the transmission structures. Ultimately, the network will comprise about 700 miles of lines. At the present it serves the three parts of northern, central and southern Greece in the following manner (see figure 7):

(i) Northern Area. A line from Agra Hydroelectric Station east to Kavalla, covering in addition the towns of Kariotissa, Salonika, Serres, and Drama.

(ii) Central Area. A circuit from Aliveri Hydroelectric Station north to the towns of Trikkala, Larissa, and Volos serving the intermediate area of eastern Greece. This will be given another extension this year and will be connected to the northern line at the Agra Station via Ptolemais.

(iii) Southern Area. A network interconnecting the Aliveri, Athens, and Ladhon Stations and serving the major towns of that area.

When the Kremasta project is completed, it will be connected to the above described network as shown in figure 7.

So far, two classes of lines have been used. Whereever a need for a large transmission capacity was anticipated the 636,000 circular mils ACSR conductor were used, while for smaller requirements the 336,400 circular mils ACSR was used.

Conventional steel towers were used for the transmission lines. Figure 9 gives a detailed picture of tower No. 206 at Euripos Straights under construction, which is typical of the towers used.

Construction of the transmission network started simultaneously with the generating stations and was completed on June, 1954.* It cost $12,880,000. The Agra-Larissa line estimated at $1,080,000 is under construction at the present.

c. <u>Step-Down Substations</u>. The step-down substations at distribution load points were planned and constructed simply with a standardized design of steel structure suitable for future expansion. Three-phase transformers rated at 3,000, 5,000, 10,000, 20,000, and 40,000 KVA were used. Most of them have nominal voltage ratings of 150-15 KV, with the low-voltage neutral grounded. Those, however, serving the capital area and those serving Yannitsa, Naoussa and Verria in northern Greece have respectively 22 KV and 35 KV low-side ratings since these are the voltages in use in these areas.

3. <u>Distribution</u>.

a. <u>General</u>. In contrast to the generation and transmission phases which were recommended by the consulting groups and approved by the Public Power Corporation to be concentrated under one authority, distribution

* To the extent indicated by solid lines in figure 7.

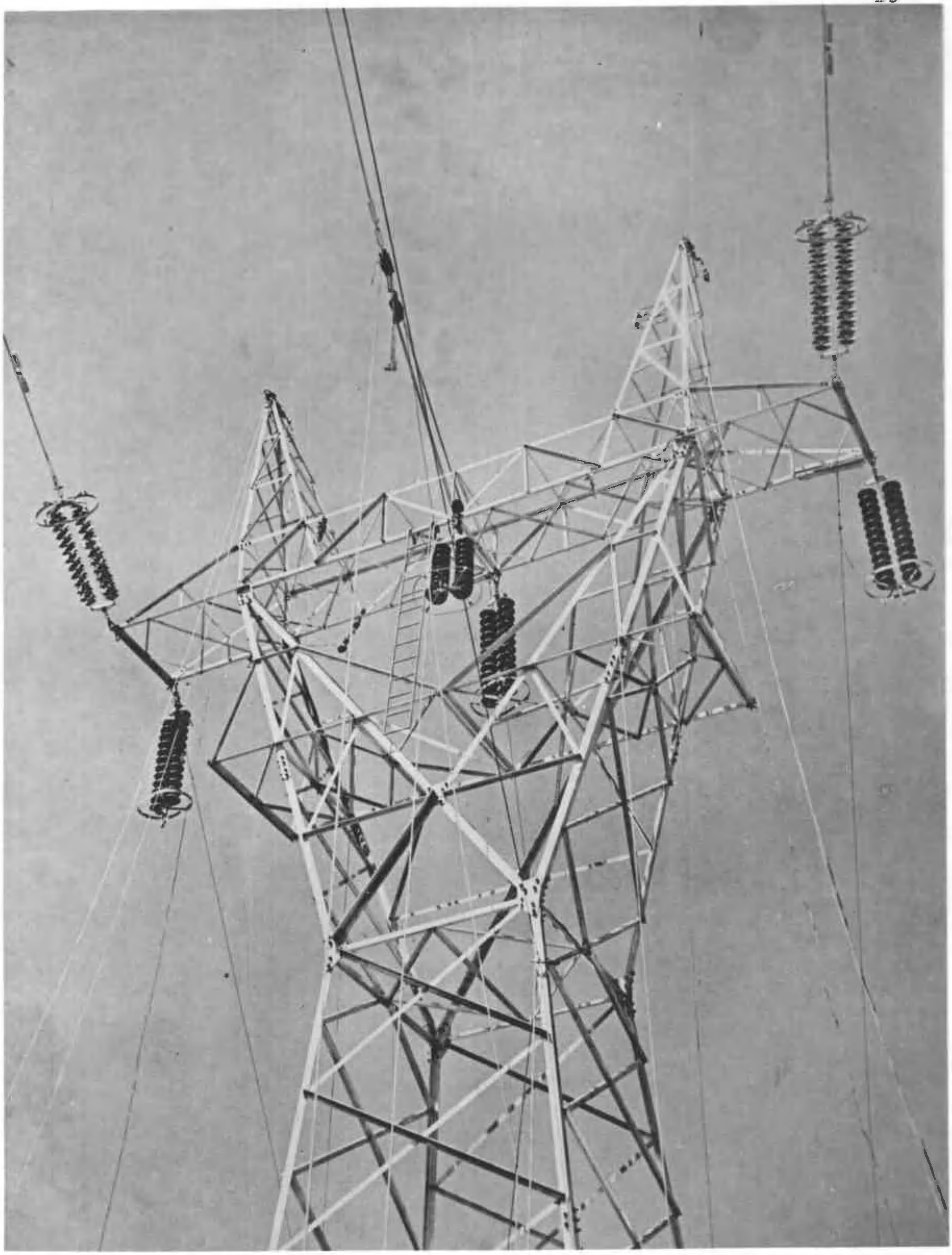

Figure 9. STEEL TRANSMISSION TOWER
Transmission tower No. 206 at Euripos Straights
(16, p.91)

was to be undertaken by a number of independent utility groups. However, this proved to be one of the major problems that delayed the development of the electrification program as it will be seen from the excerpts (18, pp. 57-58) below:

> "Organization and construction of the distribution are definitely behind. This problem of the program cannot be solved exclusively by PPC, except if the other interested groups agree on a solution dictated by the needs of electrification.
>
> "PPC proposed that according to modern techniques and for best results in serving the public, only five large distribution companies could operate. As a result, the companies within each of the respective areas should be merged ....
>
> "Since June 1951 PPC made its general principles known to the public. Therefore, enough time was present for the preparation of both the existing companies and the interested capital.
>
> "... According to compulsory laws 1672/1951 and 2113/1952 which were issued by the government after both sides were heard, PPC has the right to condemn and purchase the properties of the small companies to secure the above mentioned incorporation. The utility companies have risen against the orders of these laws....
>
> ".... Meanwhile, according to the interpretation of other laws the counties and communities of certain towns and villages claim partial ownership of the existing and new facilities as well as administrating authorities.
>
> ".... The problem is still unsolved..."

Because of this situation the progress in the distribution field of the program was confined to the parts described below.

b. <u>Voltage of Lines and Transformers</u>. The primary voltage was selected to provide maximum area coverage and load-carrying ability with a minimum number of transmission step-down substations. The voltage chosen, fifteen KV, is a standard system voltage in Europe. The primary network was almost completed at the end of 1954.

Exception to the fifteen KV primary voltage rule was made in the capital area where twenty-two and 6.6 KV are firmly established. It was found that it would be very expensive to change these voltages, since a large portion of the existing system consists of underground cable.

Because of the situation described above, only the planning of the secondary system has been completed up to date. It recommends a 220/380-volt 3-phase wye-connected multi-grounded neutral. This voltage is used extensively in many parts of Europe and is the prevailing voltage in the Athens-Piraeus area and many other locations in Greece. The transformers are to be the standard 15,000-230/398 volt.

c. Rate Structure. No definite rate structure has been used up to the present time. However, the new program was originally planned so that all of the users might be served under four basic tariffs, namely: (1) residential, (2) general for small consumers, (3) general for large consumers, and (4) street lighting.

SECTION VII

OPERATION OF THE NEW POWER PROGRAM

A. General

As a whole, the work of the Public Power Corporation must be considered as satisfactory, because it had the initiative and ability to provide Greece with a power supply system that five years ago would have been characterized as a dream even among the most optimist Greek people. Of course, many errors and delays occurred, but this will be reduced in the future through experience.

The following opinions of the authors are intended as constructive criticism.

B. Generation

It is an accepted fact, that, these rivers carry an appreciable burden of silt, sand and gravel during each flood. As a result, as time passes, solids will accumulate in the reservoir of the new projects, the dams of which, eventually, may become mere diversion dams leaving the projects without regulating facilities. Consequently, the loss of storage will reduce the total energy available from their respective dams.

The following comments refer to individual power production plants:

1. Louros Project. The choice of a fairly low-dam for the Louros development was quite successful because:

a. The project was constructed quickly because of its' simple design and thus provided many cities with electricity in the shortest possible time.

b. The low-head development needed few provisions to protect against reservoir leakage through earth formations that are noted for their porosity.

c. The site is quite accessible being located on the first-grade road joining the large city of Ioannina with the seaport of Preveza.

2. Kremasta Project. Construction on the project should start as soon as possible for the following main reasons:

a. Power need. The Kremasta project is located in an area rich in raw material suitable for the production of caustic soda, nitrogen fertilizer, sulphuric acid, and magnesium which need ample electric power. This was an important factor in the recent decision of the Athens-Piraeus Electric Company to undertake construction of a new 72,000 KW steam-electric unit.

b. Economic reasons. As it appears from table 8, the Kremasta construction cost per unit of installed capacity--$285 per KW--will be the most economic of all

Table 8

COST PER KW OF POWER CAPACITY
INCLUDED IN THE NEW POWER PROGRAM

Plant	Construction cost per installed capacity in $ per KW
Agra (constructed)	415
Ladhon (under construction)	400
Louros (constructed)	900
Kremasta (projected)	285
Megdoras (projected)	145
Aliveri (constructed)	200
Ptolemais (projected)	90
Aggregate cost per KW for the seven plants	264

the hydroelectric power plants constructed up to date. As a result this development will reduce the average cost of production of energy in Greece.

In addition, the development will reduce the use of oil-burning plants with considerable savings in imported fuel oil.

c. Military reasons. Greece now disposes of high quality ores of ferrous and non-ferrous metals located close to the Kremasta area which could be manufactured locally into ammunitions and other material necessary for war operations were low cost electric power available. It should be noted that today Greece imports most of her military ammunition, while before World War II Greek industry was receiving orders for ammunition by nations as large as Great Britain.

3. <u>Megdoras</u> <u>Project</u>. Referring again to table 8, this plant should have the lowest construction cost per unit of installed capacity of all the hydroelectric plants of the new power program. On the other hand, its' high total water head will produce much more electric power per unit of water quantity than this would have produced were it used at the Kremasta dam. At the same time, it will serve as additional control to the Kremasta Project.

4. <u>Aliveri</u> <u>Project</u>. Considering figure 7, the Public Power Corporation should be especially complimented for the Aliveri project since it is ideal because of:

a. the convenience for connection to the routing of the transmission lines,

b. the favorable location in serving the load at the Capital and Chalkis,

c. the adjacent location of the lignite deposits known for long, but used little,

d. the convenience of water presence, and

e. the nearness to modern transportation.

Furthermore, the speed with which the plant was constructed provided Greece early with electric power, something which the hydroelectric plants could not have done.

5. <u>Ptolemais</u> <u>Project</u>. This plant will have a number of advantages too, however, the authors are in

some doubt of its' usefulness. The main advantages of the project are:

a. Little transportation expense for lignite because of local deposits,

b. low initial cost as seen in figure 8, and

c. contribution of stand-by power to be used during peak periods in conjunction with the Agra Station.

Two definite disadvantages, however, are:

a. Little definite engineering knowledge concerning the lignite deposits, and

b. there is indication that this plant will soon be loaded; however, this does by no means serve the southern area where there is proportionally more demand.

C. Transmission

The authors recognize the practicability of constructing single-circuit lines as a necessity and as an initial step toward a future development. Particularly, since they realize that a choice had to be made between single-circuit lines covering a large area and double-circuit lines over fewer routes, while at the same time the financial sources were extremely limited.

Another criticism which was indirectly mentioned in the previous chapter is that the constructed transmission system favors highly the southern part of the country and in some regions completely neglects the western part; notice the northwestern part of

Peloponnesos (southern section of Greece) in figure 7.

With the exception of the above two critical points, the new transmission system is quite satisfactory.

D. Distribution.

The Public Power Corporation had the initiative to extensively use locally manufactured concrete poles for the distribution system, while, in the past, practice was to use imported wooden poles. The Corporation should be particularly praised for this decision.

SECTION VIII

CONCLUSIONS AND RECOMMENDATIONS

A. General

The new power system having a per capita installed capacity of 114.6 watts is a considerable improvement over the old which had 32.4 watts per capita. For the increased availability of electric power to most effectively contribute to the nation's well-being, the following factors should be considered and developed as favorably as possible. Most of these factors are beyond the specific scope of the P.P.C. and are more closely related to the general policies of the government and to the general attitude of the people toward the new power situation.

1. The greater amount of power that will be available will require sufficient supply of reasonably priced appliances, motors and other utilization equipment.
2. Some system of credit should be arranged to encourage people to acquire suitable wiring and appliances, so they can utilize the power that is made available. This could be undertaken either by the government or better by private finance groups.
3. The government should encourage industry to

locate throughout the country so that its load is more favorably located with respect to the power resources.

4. Industrial expansion should be developed and encouraged by credit loans and by all other means possible.
5. Small industries should be encouraged and allowed to share in the availability of raw materials as well as in the markets for finished goods.
6. Governmental regulations controlling power use should require the industrial consumers to use power produced from resources in Greece, rather than from imported fuels.
7. Use of small Diesel engines in remote and distant areas should continue, as a means of providing service and developing the towns, pending economical connection to the New Power System.

It is hoped that with the existence of the above conditions and with the help of electric power, Greece will soon become a more industrialized area and will establish a better balance of industrial and agricultural activities.

B. Power-System Organization and Policy

On the other hand, in order that this power change may be completed in such a manner as the maximum benefit may be gained, the Public Power Corporation should undertake and execute the following measures:

1. Encouragement of suitable organizations to distribute power to the ultimate consumers and to sell electricity to the ultimate consumer aggressively. Although it is understood that it will be comparatively difficult to secure private independent groups to operate the distribution system, this should be the ultimate goal in order to take advantage of the inherent incentive in a private enterprise to perform acceptably.
2. These companies should furnish better quality of service at reasonable rates and distribute the power with a minimum of interruption so that users may develop reliance on electric service.
3. The direct use of foreign capital for developments should be avoided; in case its' use becomes necessary this should be done in the form of a government loan, the proceeds of which to be used by the Public Power Corporation.

C. Technical Suggestions

Besides the above remarks the following technical or engineering problems should be considered:

1. Standard Frequency. Although the reasons for continuing the old standard frequency of fifty cycles are realized (e.g. European standard frequency, existing equipment, lower line reactances) the following facts should have been given more consideration:

a. An essentially new system provides opportunity to select the best frequency for its' operation. The fact that fifty-cycle frequency is the European standard does not prove that this is the best frequency. The European fifty cycles was chosen many years ago and is used by countries which have not recently undertaken major power developments.

b. The existence of a small amount of fifty-cycle equipment in Greece (much of which is old and practically useless) does not justify the adoption of the fifty-cycle standard that will require equipment using more copper and steel which are imported materials in Greece and therefore oppose the primary purpose of the new system.

c. The effects of line reactances could be reduced by the introduction of locally-manufactured capacitors; some capacitors are now made in Greece.

2. New Transmission Lines. There are three main

transmission line sections that would be recommended for future development:

a. A line between Agra and Larissa which will interconnect the northern and central systems which are now isolated from each other; see figure 7.

b. A line between Louros and Trikala to reinforce the Louros Station and help supply the load in that area.

c. A line from Patras through Amalias to Ladhon. This will serve the very fertile agricultural area of northwest Peloponnesos, where there is a great need for irrigation.

It is believed that with the above additions an adequate supply of electricity will be made available where required.

Finally, double transmission circuits should be installed as soon as it is economically feasible, to improve the reliability of the system.

3. Primary and Secondary Voltages. There are now eleven different utilization voltages and nine primary distribution voltages. There is now in Greece the unique opportunity to choose a single standard primary distribution voltage and a single utilization voltage which will facilitate the use and interchange of standard equipment.

4. Future Possibilities for Expansion. Greece, having limited energy resources for power production, should investigate the possibility of solving her problem

by means of atomic energy. Because, although at the present the average cost of installed capacity of this type of plant is approximately $1775 per kilowatt, this will be decreasing in the near future. Furthermore, the operating costs of the plant will be relatively low. Finally, it has been noticed that nuclear fuels have been dropping in price continuously in the last few years and the consensus of opinion is that they will become economical in the next decade.

There is an important need for a continuing study of the power needs and resources in Greece and planning for future development for power facilities. This method is the most effective way of correlating power development with needs over a long period of time and avoiding occasions when it becomes necessary to almost completely rehabilitate the system as the case was in 1948.

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