ELECTRIC POWER--AN ESSENTIAL FACTOR OF OUR NATIONAL ECONOMY

7 January 1955

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Mr. V. M. Marquis, Vice President and Assistant to the President of the American Gas and Electric Service Corporation, was born in Enid, Oklahoma, 30 March 1898. He was graduated from Stanford University in 1921 with a bachelor's degree in mechanical engineering. He received his electrical engineering degree in 1922 from Stanford University and his master of science degree in electrical engineering from Union College in 1923. From 1922 to 1928 Mr. Marquis was associated with the General Electric Company in Schenectady, New York; first in the a.c. design section and later in their Central Station Engineering Department, handling general application and power system design problems. From 1928 to 1942 he was on the Engineering Staff of the American Gas and Electric Company. During World War II he served in the Power Branch of the Office of Production Management in Washington, D. C. He later became Chief of the Power Division, Office of War Utilization. From 1946 to 1949 he was Systems Planning and Operating Engineer with the American Gas and Electric Service Corporation. He became Vice President in Charge of Systems Planning and Operations in 1949, taking part in negotiating plans for the formation of the Ohio Valley Electric Corporation and the Indiana and Kentucky Electric Corporations to supply power to the Portsmouth, Ohio, Diffusion Plant of the Atomic Energy Commission. He became Vice President and Assistant to the President in January 1954. Mr. Marquis is a member of Sigma Xi and was recently transferred to grade of Fellow in the American Institute of Engineering.

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CAPTAIN McCAFFREE: General Niblo, ladies, and gentlemen: Electric power is the common denominator in all of the industries in our vast complex. However, it is not appreciated how much and how intimately this power affects us, either industrially or in our daily lives.

Our speaker on this vital subject is Mr. V. M. Marquis; and he brings an experience of 33 years in the power industry to this platform. He is now Vice President and Assistant to the President, American Gas and Electric Service Corporation, in New York City.

Mr. Marquis, it is my pleasure to welcome you to this platform and present you to the student body of the Industrial College of the Armed Forces.

MR. MARQUIS: General Niblo, ladies, and gentlemen: I am very happy to be here and have the opportunity to discuss the subject of electric power with you.

Admiral Hague made the suggestion that the scope of the talk include an evaluation of the adequacy of the planned electric power expansion program to meet the concurrent needs of our growing economy and of national emergency, and the ability of electric power production and distribution facilities to recover from destructive enemy attacks during a possible future war. I shall comment on these broad subjects; but, first, I should like to discuss the electric power industry as it is today, and to say something about the future prospects of the industry.

As we all know, our economy is closely intertwined and dependent upon electric power for our great productivity and our many conveniences in the home. But, whether we are speaking of either peacetime or wartime conditions, it is well to remember always that the economy requires many things besides electric power. In the case of all-out mobilization, I think it is seldom the case that power is the limiting factor. It is more apt to be water, raw materials, transportation, workers, or other factors. Even in industrial operations power only represents about seven-tenths of 1 percent of the costs of the product, except in some of the especially heavy energy-using industries, such as aluminum reduction.

This does not mean that power is unimportant. Power is one of the indispensable factors in an industrial economy. It does mean, however, that power must always be considered in connection with other key factors.

At this point I might say that I have had handed out to each one of you a number of charts, which I will be referring to as we go along.

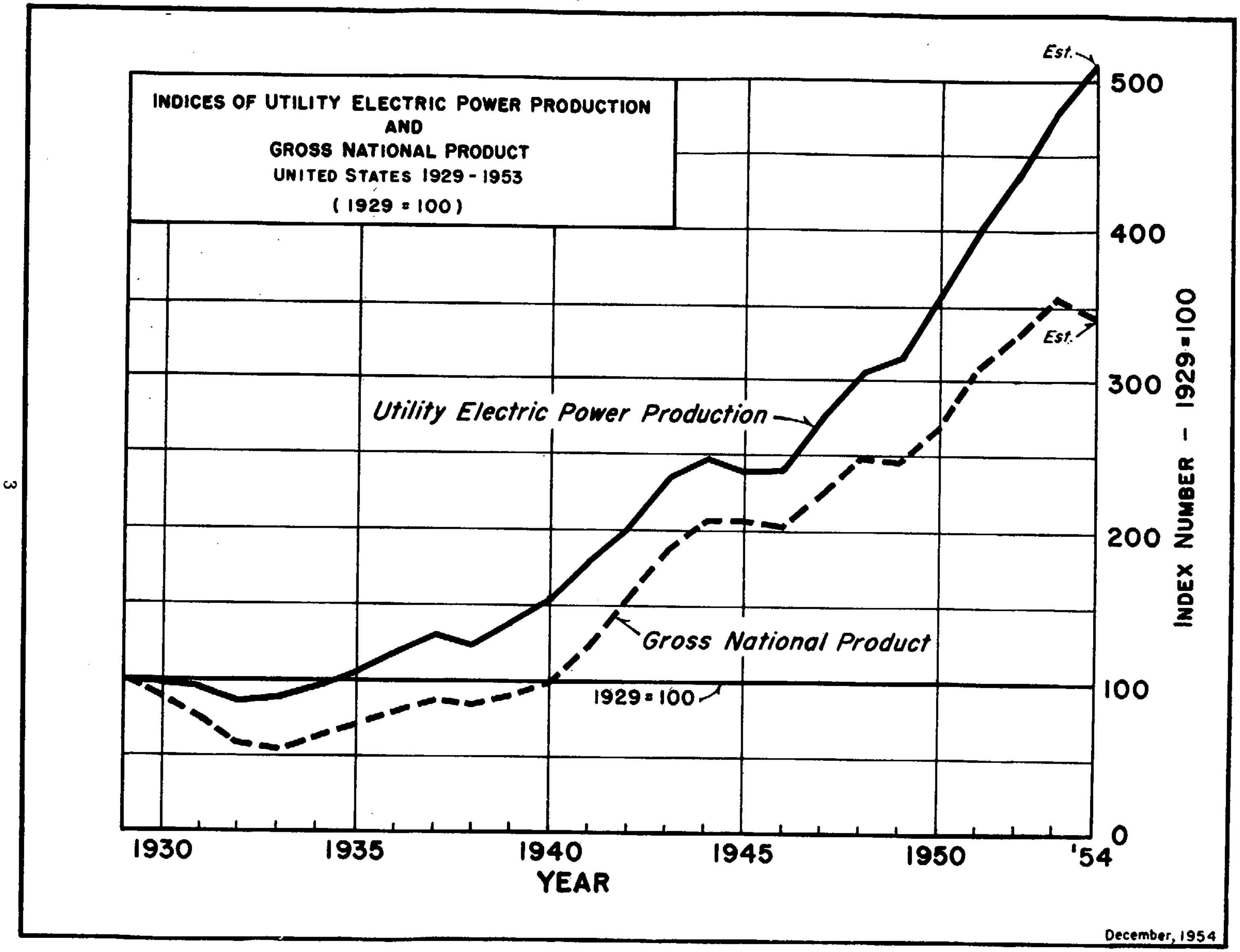
Chart 1, page 3.--The interesting relationship between electric power production and our economy may be realized by noting the close relationship between power production and gross national product (GNP). This chart carries us through a deep depression, a heavy defense and war period, the coming out of a war period, the more recent Korean experience, and the growth since that time. It will be noticed that these two curves are very closely linked, except that the power curve is moving considerably faster than the GNP curve. It is evident from this curve that the return to a normal trend was much faster after the deep industrial depression than in the GNP curve. Electric power is undoubtedly one of the essentials that helps us to get under way again and out of an industrial depression.

Chart 2, page 4.--It is also of interest to see how we compare with other countries in the production of electricity. This chart gives the latest figures on the production of electric energy total and per capita in the various countries of the world.

It hardly needs to be pointed out that the United States leads all of these countries in the production of electricity. The production by the utilities in the United States for 1954 was in the amount of 471 billion kilowatt-hours. An additional 73 billion kilowatt-hours was produced by industrial and railway plants, making a grand total of 544 billion kilowatt-hours produced in this country. None of the other countries approach this production.

In the case of the per capita figures, both Norway and Canada are higher than the United States. In each case there are special situations that account for this condition.

CHART 1


INDICES OF UTILITY ELECTRIC POWER PRODUCTION
AND
GROSS NATIONAL PRODUCT
UNITED STATES 1929 - 1953
(1929 = 100)
Utility Electric Power Production
Gross National Product
1929 = 100
Est.
Est.
500
400
300
200
100
0
INDEX NUMBER - 1929 = 100
1930
1935
1940
1945
1950
'54
YEAR
December, 1954

Country	Population (000's)	KWH Produced (000,000's)	KWH/Capita
Argentina	18,393	4,927[3]	268
Austria	6,964	8,764	1,258
Belgium	8,778	9,806	1,117
Brazil	55,772	10,308	185
Canada	14,781	71,000	4,803
Chile	6,072	3,302[1]	544
China[5]	463,493	1,879	4
France	42,860	41,556	970
Germany (Western)	48,994	61,071	1,246
Israel	1,650	759	460
Italy	48,065	32,619	679
India	372,000	6,627[3]	18
Japan	86,700	55,698	642
Mexico	28,053	5,703	203
Norway	3,359	19,622	5,842
Pakistan	75,842[2]	403	5
Philippines	21,039	1,111	53
Spain	28,528	10,116	355
Sweden	7,171	22,430	3,128
Switzerland	4,877	13,465	2,761
Taiwan (Formosa)	8,261	1,564[3]	189
Turkey	21,983[1]	1,183	54
United Kingdom	50,592	67,362[3]	1,331
United States	163,211[4]	544,000[4]	3,333
U.S.S.R.	207,000[2]	133,000	643

1 1952
2 1951
3 Utility Systems Production Only.
4 1954 (estimated)
5 1946

SOURCE: E.E.I.
U.N. Statistical Office

Chart 3, page 6.--To carry this comparison a little further, it is of interest to look at this chart and to note that our position, as compared to other countries, in the production of electric power has remained about the same over the entire period from 1920 to date, in the length of time shown on the chart; and accounts for around 40 percent of the world's production of electricity.

Another point of interest is the growth in production by Soviet Russia. It accounted for about only four-tenths of 1 percent of the world's use in 1920; but this has grown to 10.6 percent in 1952. And, of course, it is higher than that now.

It will be noted that in the case of West Germany the trend has been downward. However, it seems quite certain that this trend will reverse and come back more nearly to its proper position.

Chart 4, page 7.--This chart gives some idea as to the kind of job that has been done in the United States over the past 30 years or so. From this it can be seen that the population increased some 50 percent, while total electric energy increased some 800 percent, or 16 times as much as the population. This suggests what has been done in this country in making an abundance of power available for all needs.

Expansion of power facilities is still continuing in this country at an accelerated pace. The best estimates today are that the use of electric power in the United States will double over the next 11 years, and this is about what has been happening in the past. Actually, from the period 1925 through 1953 the long-term, annually compounded growth trend was 6.4 percent; for the period 1932-53 it was 7.5 percent; and for the period 1939-53 it was 8.1 percent. These figures apply to the electric utility industry, but do not include production in electric power plants owned by industrials.

Since the end of World War II, the capability of the utility systems has about doubled. On 21 October 1954 the combined utility facilities in this country reached a capability of 100 million kilowatts. This was something of a tribute to the 75th anniversary of the discovery of the electric light by Thomas A. Edison, an event that has been celebrated this year as the Golden Jubilee of the Electric Light.

During 1954 the generating capability of the systems was increased by 11.5 million kilowatts, while in 1953 the increase was just over 10 million kilowatts. Some 12 million kilowatts is scheduled for completion

CHART 3

ESTIMATED WORLD PRODUCTION OF ELECTRIC ENERGY
PERCENT OF USE BY THE UNITED STATES
AND VARIOUS OTHER COUNTRIES

IN MILLIONS OF KWH

YEAR	1920	1930	1940	1950	1953
World Production	126,000	310,000	505,000	919,000	1,245,700
U. S. Production	56,559	114,637	179,907	388,674	513,518
Percent Use:					
United States	44.9	37.0	35.6	42.3	41.2
Canada	4.7	5.8	6.7	6.2	5.7
United Kingdom	5.1	5.3	6.7	6.0	5.4
France	4.3	5.0	3.4	3.8	3.3
U.S.S.R.	.4	2.7	-	9.8	10.7
Japan	5.5	4.5	6.1	4.2	4.5
Germany	6.8	9.35	12.5	4.8 *	4.9

SOURCE: E.E.I.
*West Germany Only

CHART 4

POWER PRODUCTION AND GROWTH IN POPULATION IN THE UNITED STATES 1920-1954

Year	Population (000's)	KWH Produced (000,000's)	KWH/Capita
1920	106,466	56,559	531
1925	115,832	84,666	731
1930	123,077	114,637	931
1935	127,250	118,935	935
1940	131,070	179,937	1,373
1941	133,203	208,307	1,564
1942	134,665	233,179	1,732
1943	136,497	267,540	1,960
1944	138,083	279,525	2,024
1945	139,586	271,255	1,943
1946	141,235	269,609	1,909
1947	144,024	307,400	2,134
1948	146,571	336,808	2,298
1949	149,215	345,066	2,312
1950	151,689	388,674	2,562
1951	154,353	432,319	2,801
1952	156,981	462,589	2,947
1953	159,696	513,518	3,216
1954	163,211*	544,000**	3,333

* Estimate as of October, 1954, Dept. Comm.
** Estimated by E.E.I.

in 1955, with some tapering off in 1956 and 1957. The rapidly expanding use of electricity will call for new capacity of about this amount to be added each year; that is, something of the order of 10 or 12 million kilowatts.

Chart 5, page 9.--With such large yearly increments of new generating capacity, it is of interest to review what has happened to the operating efficiency of these new units. This chart shows the improvements in efficiency in the generation of electric power during the rapidly expanding period from 1940 to date and estimated through 1968. The curves show the British thermal units of heat energy required to produce one kilowatt-hour of electricity during the 14-year period, and the expected further increase in efficiency during the next 14 years.

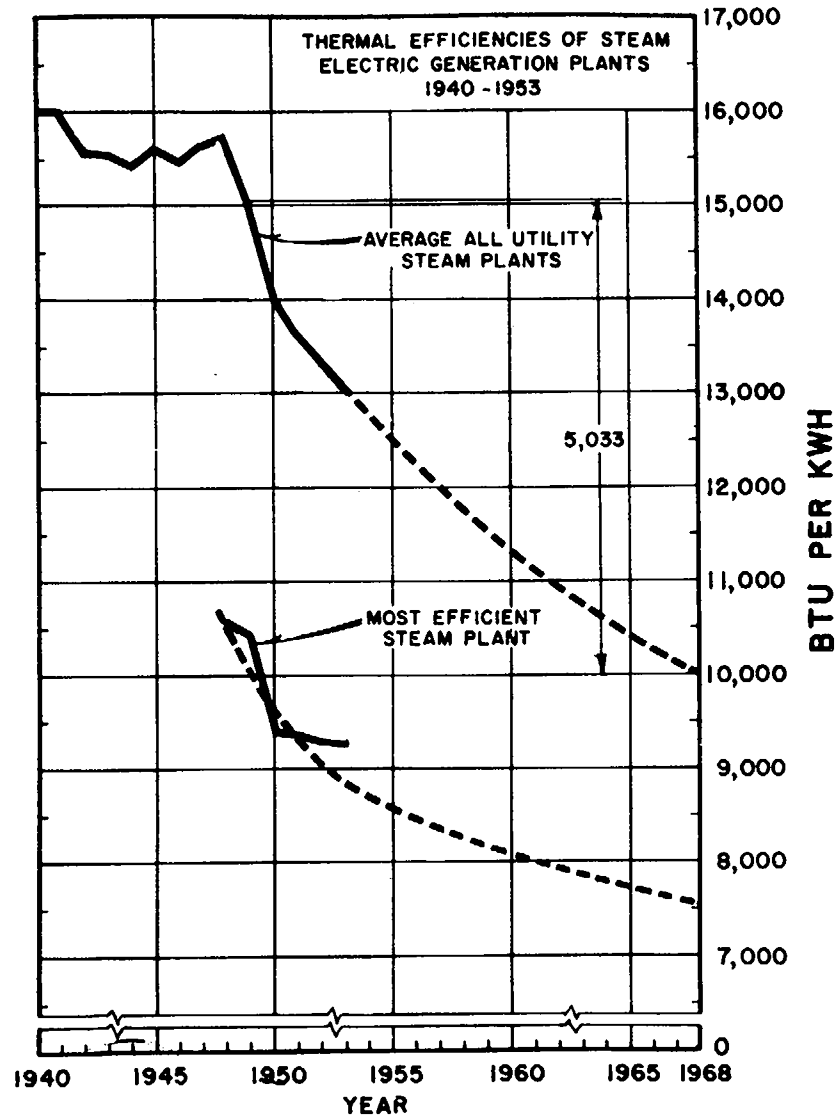
Let me stop here to say that a BTU is the amount of heat required to raise the temperature of one pound of water one degree F at maximum density, which I believe is around 40 degrees F. One kilowatt-hour is the equivalent of about 3,415 BTU's. So that, if you have a 100 percent efficiency, you get a kilowatt-hour for 3,415 BTU's.

The average for all utility plants decreased from 16,000 to 13,000 BTU's per kw.-hr. from 1940 to 1954. We have estimated that in projecting this to 1968 a further reduction from 13,000 to 10,000 is to be expected. This estimate is justified by a look at the second curve, showing the performance of the most efficient steam plant in the country. There is, of course, a direct relationship between the average performance and that of the new and most efficient plants.

During the last seven years the most efficient plants in the United States, and in the world, for that matter, were as follows: In 1948 the Port Washington plant in Milwaukee, Wisconsin Power and Light Company, 10,588. In 1949 Sewaren, Public Service Electric and Gas of New Jersey, 10,437. Then from 1950-54 we were fortunate enough to hold the record in our system. In 1950 it was the Phillip Sporn, with 9,378; in 1951, Tanners Creek, with 9,354; again in 1952, Tanners Creek, with 9,303; in 1953, Kanawha, with 9,249; and in 1954, Kanawha again, with 9,099.

We expect the new Philo No. 6 unit on the A. G. & E. system will have a heat rate of above 8,500 BTU's per kw.-hr. This is a little over 40 percent thermal efficiency.

CHART 5


THERMAL EFFICIENCIES OF STEAM ELECTRIC GENERATION PLANTS 1940 - 1953
AVERAGE ALL UTILITY STEAM PLANTS
MOST EFFICIENT STEAM PLANT
5,033
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
0
BTU PER KWH
1940
1945
1950
1955
1960
1965
1968
YEAR
December, 1954

This Philo unit will be the first one in the country to operate above critical pressure. The pressure will be 4,500 pounds and will have two stages of reheat. The initial temperature will be 1150 degrees. The first stage of reheat will be 1050, the second 1000.

In another decade the industry should reach heat rates of around 7,500 BTU's per kw.-hr., and perhaps reach 7,200 by 1975. To achieve this goal will require a great deal of research and experience, but I am sure it will be reached.

In other words, looking at this industrywide, 28 billion more kilowatt-hours than in 1953 were produced in 1954, out of the same amount of coal. The gain was about 8.2 percent.

Expansion naturally requires that large sums of money must be raised by the utilities. It is reasonable to expect that to finance the program may require an average of almost 5 billion dollars per year over the next 15 years. The utility industry is confident that it can raise the money required to carry out this program.

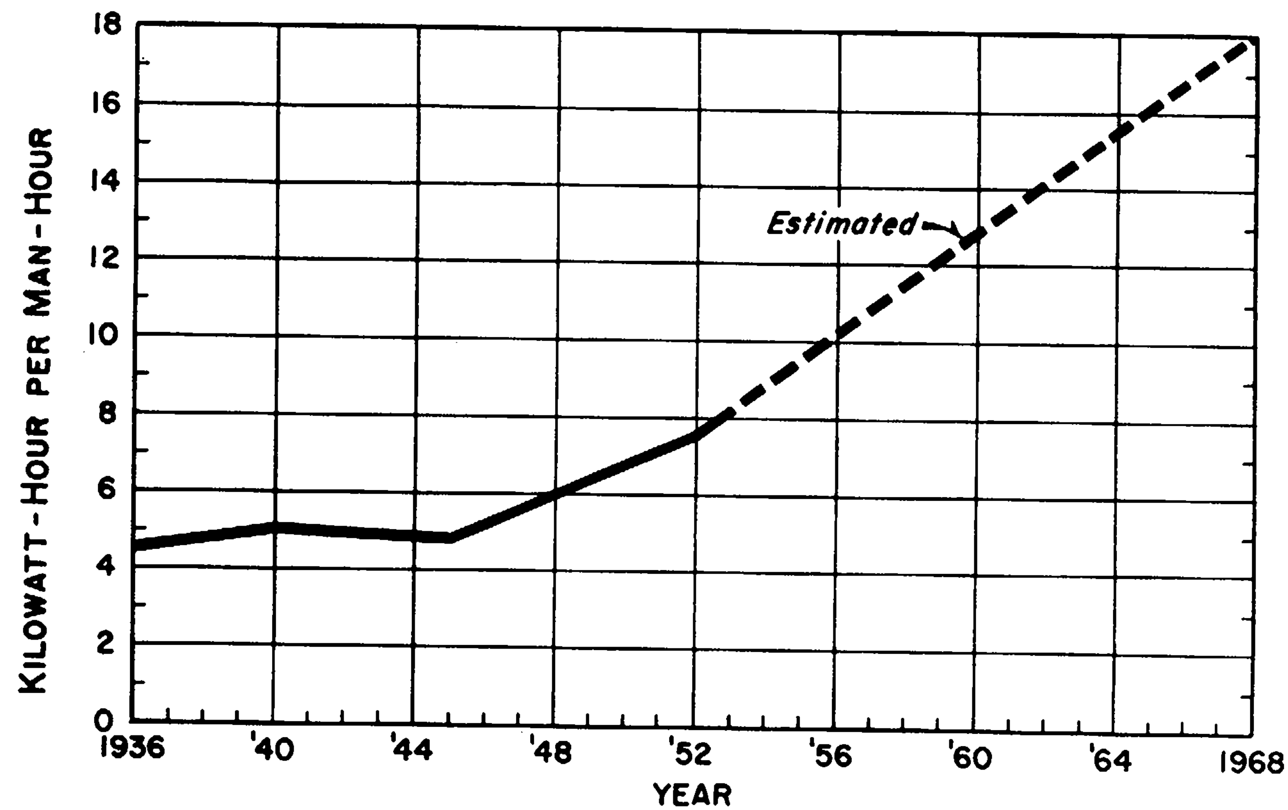
There are also many reasons to expect a continued growth in the use of electric energy. Just as an example, the average annual residential use in this country has increased from 447 kw.-hr. in 1930 to 2,540 kw.-hr. in 1954; in some areas it is above 5,000.

Sales to domestic customers alone in 1954 were greater than the total sales to all classes of customers only 15 years ago. A home with all the major appliances, including the heat pump, may use as much as 20,000 kw.-hr. per year. There are many such homes at present. Every home in the country certainly will not have a heat pump; however, this device is really beginning to take hold, and will be used extensively in the future. Some homes will use electric space heating and air conditioning instead of the heat pump. These major uses, along with all the other appliances in the home, will greatly increase domestic consumption of electricity. Most farms in the United States are now electrified, but for the most part they are just beginning to take advantage of electric power; and for this reason farm use will gradually be expanded. Use in the commercial field, likewise, is growing at a rapid pace.

Chart 6, page 11.--One of the best ways to see what is happening in the use of electricity in industry is by reference to this chart which shows the actual and predicted kilowatt-hours per man-hour use.

CHART 6

PREDICTED KILOWATT-HOUR PER MAN-HOUR IN INDUSTRY



Source: Electric Light & Power and General Electric Apparatus Sales.

December, 1954

In 1940 the kilowatt-hours per man-hour in industry were about 4.9. By 1952 it had risen to 7.6. It is estimated that by 1968 it will be about 18. This trend will continue. It is the way our national productivity and production per man-hour have been brought up in the past, and is undoubtedly the way that increased productivity in the future will be accomplished.

The electric industry has grown at a rapid pace as a result of the normal demand for power and due to the aggressive selling campaigns of the utilities. But the questions naturally arise as to how well the industry could meet a sharply stepped-up or all-out mobilization program; what additions would be needed during the period; and what position the utilities would be in to meet the recovery program after the emergency is over.

In case we were faced with an all-out effort, quite a number of things would happen that affect the power situation. A great many factories would immediately start manufacturing products for mobilization. Thus some of these special requirements would be met by displacement. In certain areas the industrial power load would actually drop off until complete conversion could be accomplished. The manufacture of many peacetime items for civilian use would probably be stopped and would release some power for other uses. Simultaneously, the design and construction of many new factories would be started for the production of additional war materials.

In most cases new factories can be built considerably faster than electric power plants. As a rough guide to this, industrial plants could probably be built in from less than a year to perhaps 18 months, while power plants require between two and three years.

Fortunately, to meet this potential unbalance, we have considerable cushion. This consists of encroaching on our reserve capacity, that is, the difference between our generating capability and the load we will have to carry; and by adopting nationwide daylight-saving time; and by making full use of all facilities of the large interconnected system groups.

Also industry would go to additional shifts, and this would be a gain. In World War II the average utility system's load factor increased from about 60 percent to 67 percent, resulting in an equivalent increase in production at no increase in peak demand. It is, of course, well known that by working three shifts, you don't produce three times as much.

But just where would this leave us powerwise if we faced such an emergency in the near future? How, for example, would we compare with World War II experience? Actually, in World War II the heavy defense program started in 1939, and at that time the utilities had about 38.9 million kilowatts of capacity and a load of some 28.7 million kilowatts, or about 10 million kilowatts of gross margin or reserve. In percentage this amounted to about 35 percent. The reserves were high at that time because the load had dropped off very sharply during the depression and had not yet returned to anything like normal trends.

Chart 7, page 14.--This chart shows the actual generating capability load, gross margin, and percent margin for 1953-54; and the estimated values for 1955, 1956 and 1957. Chart 8, page 15, shows these same data in chart form.

It will be seen, for example, that in 1953 the capability was a little over 92 million kilowatts and the load about 78.5 million, giving a gross margin of 13.8 million kilowatts, or 17.6 percent. It is estimated that by 1956 the gross margin will be close to 21 million kilowatts, or 25 percent. This shows that, although the percentage is considerably lower than 1939, the actual gross margin in kilowatts is at the present time considerably greater than 1939. In 1954 the capability reached about 104 million kilowatts, the load about 87 million, leaving a gross margin of almost 17 million, or a little over 19 percent.

This means that at the present time our reserves in kilowatts are substantially higher than they were at the beginning of the defense period prior to World War II. The general thinking throughout the industry since World War II has been that the gross reserves, that is, the difference between load and capability, should be about 15 percent. Our own thinking in connection with system planning is that 13 percent is adequate under present conditions; and that, as time goes on, that would increase as we go to larger generating units.

The reserves at present are considerably above the 13 to 15 percent now, because loads in some areas have been somewhat below those predicted at the time the present new capacity was commenced. A return to the normal trend will gradually close this gap.

The purpose of reserve generating capacity on utility systems is to take care of scheduled and emergency outages of equipment and to provide for load growth. At least the portion held for load growth can

CHART 7

LOAD AND CAPACITY SITUATION
ELECTRIC POWER SYSTEMS OF THE UNITED STATES

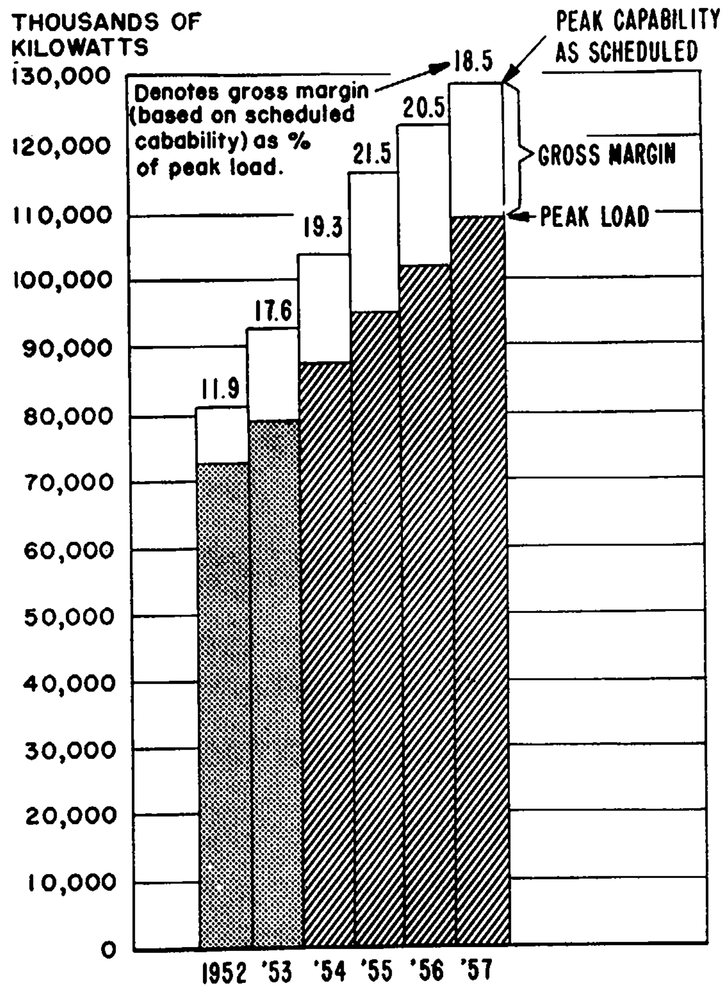
YEAR	CAPABILITY MW	PEAK LOAD MW	GROSS MARGIN MW	GROSS MARGIN %
1953	92,336	78,531	13,805	17.6
1954 [1]	104,154	87,322	16,832	19.3
1955 [1]	116,537	95,893	20,644	21.5
1956 [1]	123,418	102,452	20,966	20.5
1957 [1] [2]	129,297	109,113	20,184	18.5

[1] Estimated

[2] 1957 capability additions not completely scheduled

SOURCE: E.E.I.

CHART 8



PEAK CAPABILITY represents the maximum kilowatt output with all power sources available. It must, therefore, provide the necessary allowance for maintenance, emergency outages, and system operating requirements.

GROSS MARGIN includes the provision for maintenance, emergency outages and system operating requirements. Any remainder, after these needs are met, is available for unforeseen loads.

Total U. S. December Peak Capabilities and Peak Loads, 1952 Through 1957 — Median Hydro Conditions

SOURCE E.E.I.

safely be used for added mobilization loads, and we could encroach on reserves normally desired for scheduled and emergency outages, at least during the initial periods of fast load buildup. Thus it should be safe in a national emergency to perhaps reduce reserves to about 8 percent, but with a definite plan to at least maintain this value and try to improve it once the initial impact has been met.

But actually, when you have 8 percent reserve, you have really no reserve in terms of load growth, because it will require about that much to take care of the scheduled and emergency outages of generating equipment.

Then there is the matter of system regulation. On these large interconnected systems it was found that optimum results are obtained if system frequency is closely controlled. As systems grew it was found almost impossible to control frequency manually at the many stations. This led to automatic frequency control. It was necessary to refine the automatic control by a so-called bias feature. This makes it possible for each generating plant or system to furnish its proper share of regulating capacity for frequency control, and at the same time normally maintain scheduled loading on interconnecting transmission lines.

So for these reasons it is important to maintain proper reserve capacity on the system. It is very difficult to sell this idea during times of national emergencies--as we found by experience during World War II, and more recently, during the Korean War.

If we assume a case in the future where our reserves were about 15 percent, we would have 7 percent available for interim power requirements on the basis of the minimum reserves just mentioned. If we assume the load at that time is 125 million kilowatts in the country, that would give us about 8.75 million kilowatts of available capacity. Undoubtedly we would go to nationwide daylight-saving time and probably pick up another million and a quarter of peak capacity. This would bring us up to 10 million kilowatts, which could be further increased by very close supervision of the operation of the widespread interconnected systems. This would assume, of course, that whatever construction program was under way on the part of the utilities would be allowed to be carried through to completion. It would thus appear that, should an emergency occur in the near future, we would be in excellent shape to get the initial necessary industrial expansion under way.

But, since load growth will occur, new generating capacity must be added if we are to maintain even the reduced reserves. During the initial stages of World War II, the power facilities scheduled or under construction were immediately reviewed, and many projects were stopped to save critical materials. Work was halted on projects totaling some 4 million kilowatts. For approved units and plants, every effort was made to maintain required operating dates by improved priority ratings. But even with this assistance very few units were operating on scheduled dates. As the war progressed, other capacity was scheduled to meet the increased requirements, but the need for each proposed new addition was scrutinized closely and approved only if it met certain criteria.

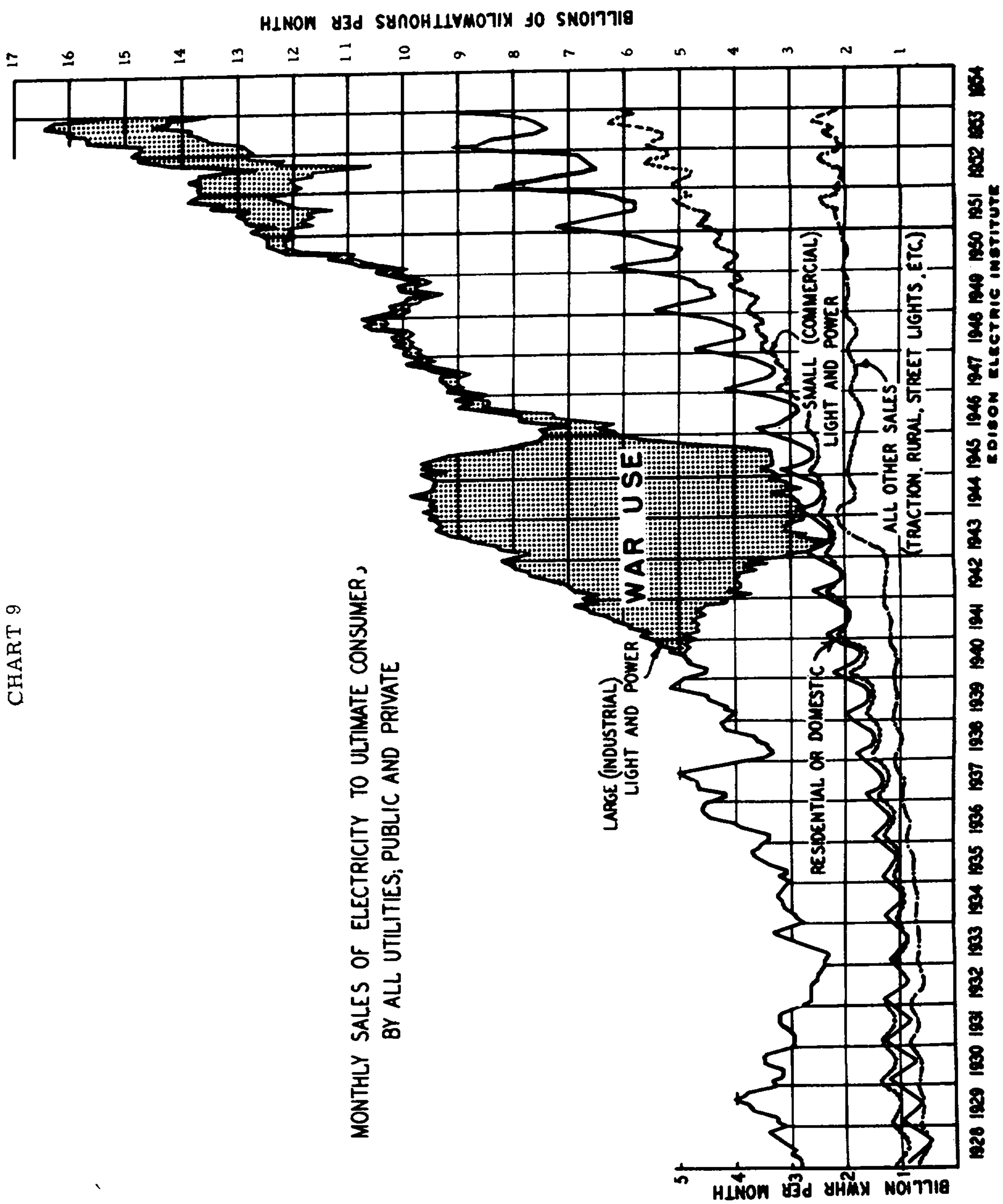
At this point a word of caution should be given. It isn't possible to suddenly stop or cut off for any appreciable length of time the addition of new facilities to the power systems without adversely affecting the economy, whether we are at war or at peace. It takes a long time to build and install new facilities, and this is especially true during national emergency periods. That maximum use of all available power facilities should be made goes without saving, but those in charge of material allocations should see to it that a fair share is used to maintain electric power margins at a safe level. In World War II it appeared to me that too many expected that power should be available in any magnitude at any desired spot without adding new facilities as the demands grew; that it should just be there.

Chart 9, page 18.--This chart shows the impact of defense and all-out mobilization on the requirements for electric power. On this chart is plotted the monthly kilowatt-hour sales to consumers by private and public utilities during the period 1928 through 1954. Total sales are broken down into three broad classifications--namely, sales to the large industrial users; sales to residential, domestic, and small commercial; and sales to all other customers, including rural, traction, street lightning, and others. In World War II civilian use was cut back very little, so that our main interest on this chart is the performance of the curve showing industrial use of power.

From this curve it can be seen that not only was displacement very substantial, but also that the industrial load continued to grow during the period. On this curve, the area below the normal trend curve represents the amount of displacement.

Perhaps the best example of displacement during World War II, and at other times, was the automobile industry, where they immediately

CHART 9



MONTHLY SALES OF ELECTRICITY TO ULTIMATE CONSUMER, BY ALL UTILITIES; PUBLIC AND PRIVATE commenced to convert and eventually began building tanks and other war equipment instead of automobiles for civilian use. But the total industrial load continued to climb and represented the combined effect of more intensive use of existing industrial plants and the coming into operation of new defense facilities.

Chart 9 also shows that civilian use was practically not curtailed at all during World War II. There was some slowdown in growth, principally because some energy-consuming devices could not be obtained.

Since available reserves play such an important part in any discussion of the adequacy of power to meet a sharply stepped-up or all-out mobilization, the first step would always be an examination of available generating reserves; and this logically leads to the further question as to whether these reserves would be properly distributed and in the desired locations.

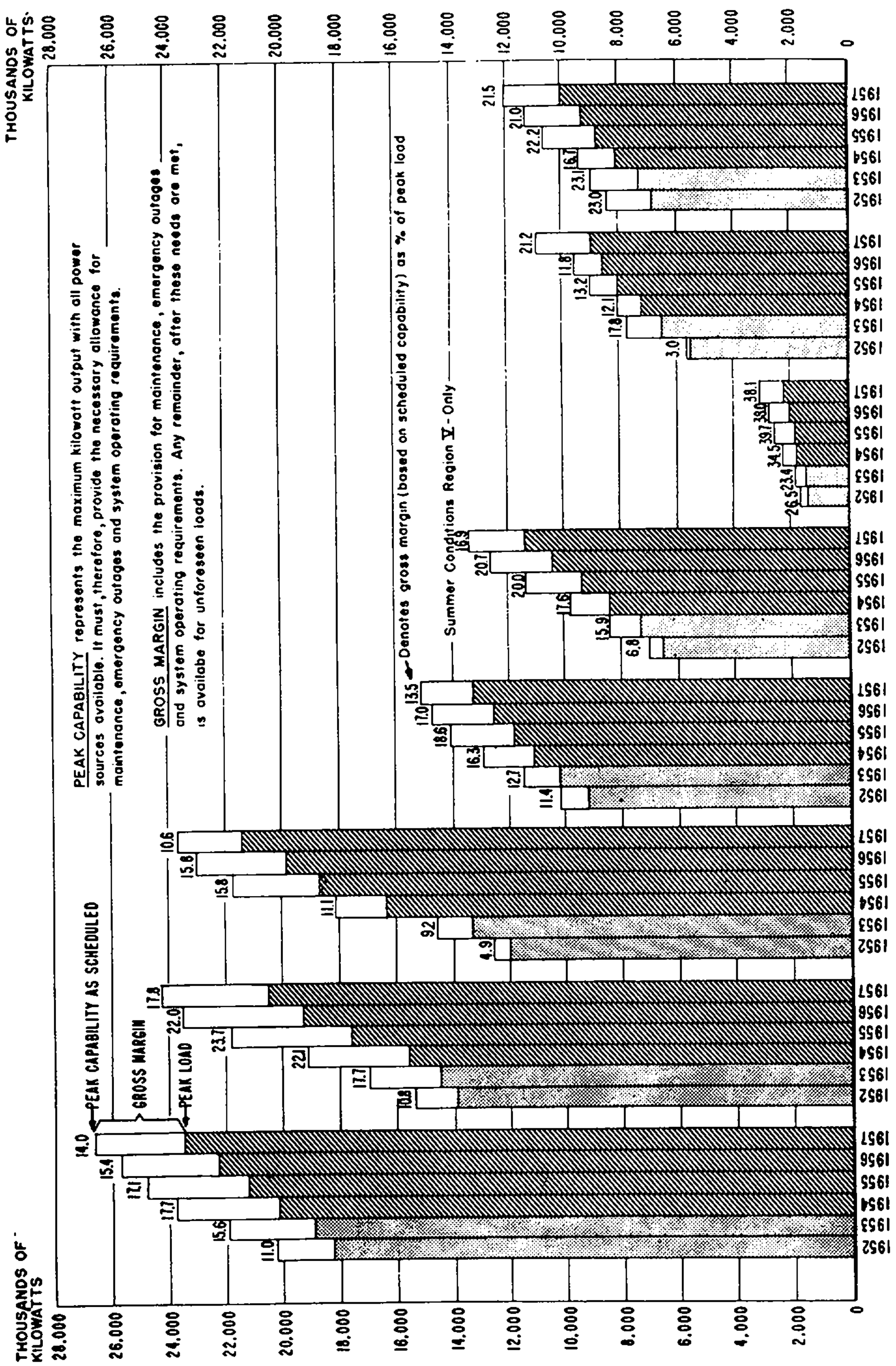
Chart 10, page 20.--This chart relates to the second question, that is, the distribution of reserves throughout the country. It shows the load-capacity situation during the years 1952, 1953, and 1954, and expected conditions through 1957 for each of the eight power-supply regions as designated by the Federal Power Commission (FPC). It will be seen that reserves are in general comparable in each region of the country.

This, of course, does not necessarily mean that a new heavy load can be located at any point in the country without the addition of new power facilities. However, as I will show you a little later, the systems in the various areas of the country are on the whole well interconnected, and, therefore, can make power available generally throughout the areas. In many cases it would be necessary to add some transmission facilities, but this can normally be done very quickly and without using much in the way of critical materials.

Chart 11, page 21.--This chart shows the main transmission systems in the United States. I am sorry that it was impossible to show much detail on the small chart. However, it will give you some idea of the extensive transmission networks in this country.

Superimposed on this map are the eight FPC power-supply regions. Large interconnected groups of utilities operate in each of these regions, and in some cases include several or parts of several regions. There are five extensive interconnected groups in the country, that at present account for 80 percent of the total load of the country. These are:

CHART 10

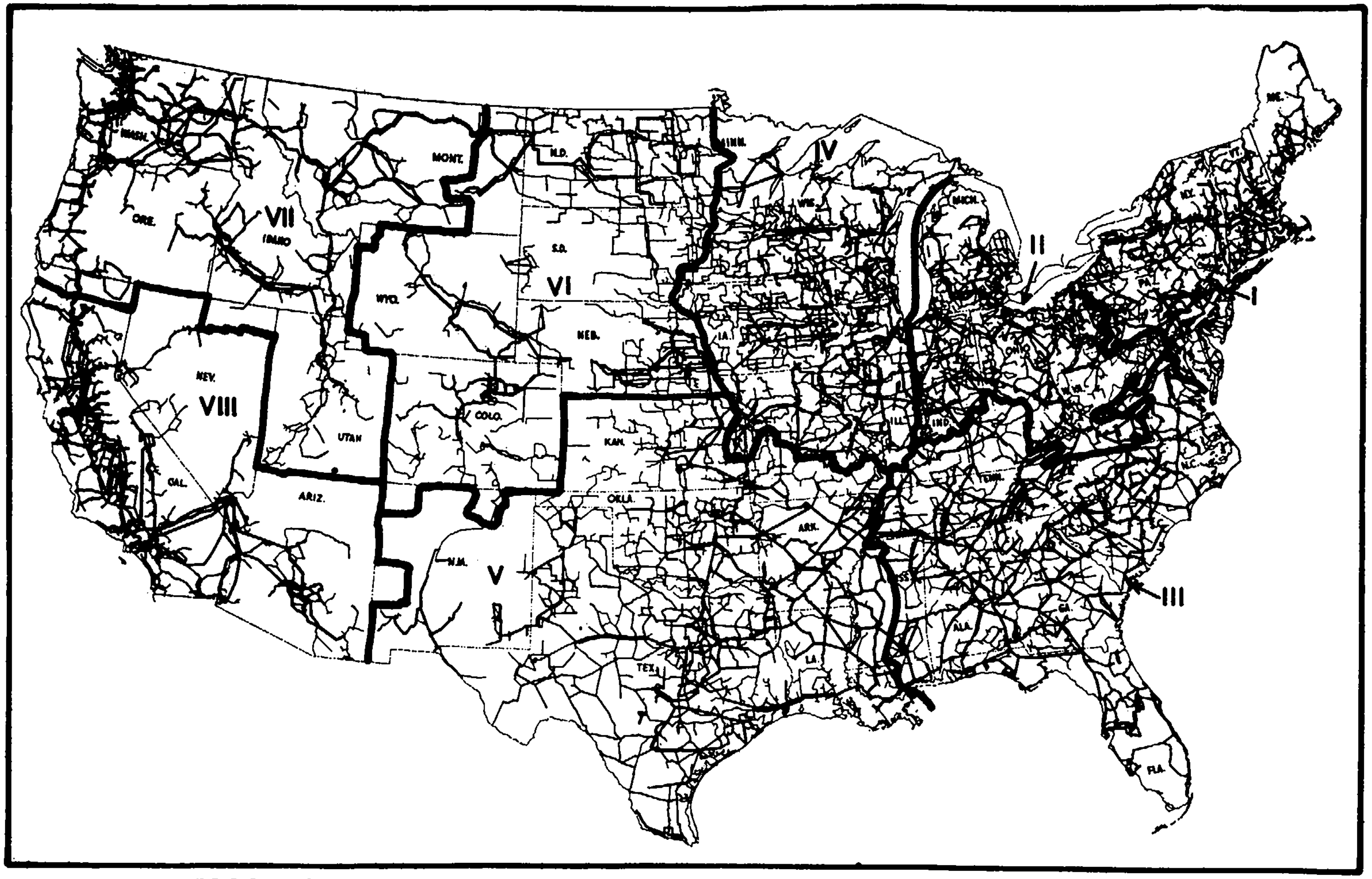


Regional Peak Capabilities and Peak Loads, 1952 Through 1957 — Median Hydro Conditions

For Region V, summer conditions are shown. December conditions are shown for all other regions. Figures for 1952 and 1953 represent actual operating data.

SOURCE E.E.I.

CHART 11



Roman numerals indicate F.P.C. Power Supply Regions

F.P.C. Power Supply Regions, Superimposed on Map of Principal Interconnected Electric Transmission Lines

SOURCE E.E.I.

1. The New York-New England group.

2. The Eastern Pennsylvania-New Jersey-Baltimore-Washington group.

3. The East Central-Midwest group.

4. The Pacific Northwest group.

5. The Pacific Southwest group.

The largest group which operates interconnected and in parallel continuously is what might be termed the East Central-Midwest, located all or in parts of regions 2, 3, 4, and 5. This includes systems in all of 17 states and parts of another 7, and extends from the Great Lakes to Florida, from central Pennsylvania west to include most of Kansas, Nebraska, and Oklahoma, and includes the eastern part of Texas.

During the war all major systems in Texas operated in parallel with this group. Except for the southwest part of Michigan, the other major systems, although well interconnected, do not interconnect with utilities outside the state. The main reason for this, as well as the Texas case, and other similar cases in other parts of the country, is that these systems want to maintain their intrastate status. During periods of national emergencies, interstate lines in such cases are brought into operation, and the FPC would normally waive jurisdiction for the period of the emergency.

This large interconnected group reached a peak of about 35 million kilowatts in the year just past, or about 33 percent of the total utility load of the country. It is interesting to note that the three AEC gaseous diffusion plants at Oak Ridge, Paducah, and Portsmouth are connected to this vast system.

Since the principle of making reserves available throughout interconnected systems operates in the same manner on all such systems, this might be a good point to mention that very substantial amounts of power can be exchanged between the individual systems of any such group of systems. Straight-away long-distance transmission of power is not required for systems in Ohio to help those in Florida and vice versa. Rather, it is a matter of substitution between intervening systems, in other words the old bucket-brigade principle.

How reserves may be utilized to furnish interim power until permanent facilities are completed is illustrated by the power supply to the AEC gaseous diffusion plants. Although these new AEC facilities can be built much faster than the new power plants which must be built to supply them, AEC has been able to operate its facilities as quickly as built, through interim power furnished by drawing on utility reserves. Systems around the TVA area, for example, have at times furnished up to 50,000 kilowatts continuously to TVA for AEC. Similar amounts of interim power will be required at Portsmouth until the permanent power facilities are in operation. These large groups of systems are experienced in operations of this kind and in meeting daily emergencies that occur in the normal course of events.

Moving to the northeastern section of the country, the New York-New England group includes all systems in the area except those in the State of Maine, and these only operate in parallel during emergencies, since the state has a law prohibiting the export of power from the State of Maine. This group serves a load of about 11.5 million kilowatts at the present time.

The Eastern Pennsylvania-New Jersey-Baltimore-Washington group has a present load of about 8.5 million kilowatts. The group has several ties with the New York-New England group, but usually only operates them during emergencies or under special conditions.

In the Pacific Northwest, the systems in Washington, Oregon, Idaho, Utah, and Montana operate interconnected and in parallel. The system of the Bonneville Power Administration is included in this extensive network. This group serves a load of close to 7 million kilowatts, including the important aluminum-reduction plants and aluminum sheet mills, copper mines, and reduction plants in Montana and Utah and a steel mill in Utah.

In the Pacific Southwest the systems in California, Nevada, and Arizona operate in parallel, and serve a load of close to 9 million kilowatts. It is interesting to note that during World War II the Southern California Edison Company, one of the large systems in that region, operated substantially all of its system at 50 cycles. This materially complicated the problem of interchange of power between systems. Since that time the entire system of Southern California Edison has been changed over to 60 cycles, and this bottleneck completely removed. The northern part of California has an interconnection with an adjacent system in Oregon; however, Pacific Northwest and Pacific Southwest do not operate in parallel. The systems are normally split in Oregon when power is required from California.

Some of the smaller but still important interconnected groups are those in parts of Wyoming, Colorado, and Nebraska, serving a load of about 800,000 kilowatts; the eastern Wisconsin group, with a combined load of almost 2 million kilowatts; and the Texas group, with a load of about 3 million kilowatts.

This leads to the question of whether any additional benefits would result if all systems in the country were interconnected. I think the answer is "No," and that we couldn't afford it at the present time.

That this might happen over a long period of time as a result of normal growth of the systems would not surprise me. These vast networks are being constantly strengthened as new power plants and associated transmission are built. In some sections of the country higher-voltage transmission lines of the 330,000-345,000-volt class are being installed, and some are already in operation. This tendency will spread, and ultimately some higher voltage will be superimposed on the existing high-voltage networks. This will greatly strengthen these interconnected systems to keep in pace with growing loads. This appears to me to be an orderly way for this development to take place.

There are, of course, some transmission bottlenecks within these interconnected networks. In case of an all-out mobilization of our productive facilities, there would undoubtedly be some cases where ties between systems or areas should be strengthened, depending on where new war loads were placed. However, if materials are made available, these ties can be constructed in a relatively short period of time and as fast as new power-consuming facilities can be placed in operation.

Previously I mentioned that additional capacity could be made available in an all-out effort by closer coordination of the operation of these interconnected systems. This comes about by the fact that the degree of coordination, taking the entire network as a whole, will vary in most cases in peacetime and during full-scale mobilization. In the latter case all existing facilities will probably be pushed to the limit, and in such cases cost may of necessity be a minor factor.

For example, older generating units, normally operating only during peak load periods or held as cold reserves, would be run continuously. All generating units would be pushed harder. Lines and other facilities would be loaded beyond normal practice to serve greater loads, despite resulting higher losses. Normal maintenance programs would be reduced; closer attention would be given to the coordination of planned outages. By these and other emergency measures, substantial amounts of additional power would be marshaled for mobilization.

In peacetime the many benefits of interconnected and coordinated operation of these networks are realized, but great stress is placed on reaching the maximum operating efficiency. Thus it is general practice to interchange so-called economy energy. This simply means operating the most efficient units and backing down on less efficient units whenever the system load permits. These monetary savings are divided between the interchanging companies.

These interconnected systems give the best insurance for meeting the two major problems in the case of all-out mobilization, namely, to make possible the full use of all power facilities wherever they are located and to minimize the effect of sabotage and bombing.

In any discussion of protection, it would be helpful to know what we will have to cope with. What type of bomb will our enemies use, and will they bomb population or production facilities? Will it be a very short war, or will it last a year or several years? These questions have a definite bearing on the problem of maintaining continuity of electric service.

Many people who should be in a position to know, felt that in World War II the German power system should have been a number one target early in the war. What would be the strategy of an enemy in the future, I do not know. But, if the bombs are atomic and their main objective is population centers, then if power could be used at all in or on the fringes of the bombed area, it could be brought in from outside sources.

But, even if power systems are prime targets, it is inconceivable that power plants could be put out of commission without also destroying or damaging some of the loads they serve. In most cases the utilities could have power available much faster than many of the power-consuming devices could be replaced.

Now, this appears at first a contradiction of what I said before--that it takes longer to build power plants than it does to build industrial plants. But I think the point is that our power plants are highly dispersed, and they are tied together by strong interconnected systems.

Thus it should be possible to bring in power from other sources in these cases.

There would naturally be many difficult problems, and this is not an attempt to minimize them. However, with the interconnected system, with reasonable spares and repair parts, along with any necessary Government assistance in obtaining any required materials and equipment, and, above all, experienced people, it should be possible to maintain service with a high degree of continuity.

After World War II a great deal was said about this problem of protection; and, of course, there is still a great deal of thought being given to it. Some called for such extreme measures as putting power plants and industrial plants underground.

The problem becomes one of taking all factors into account, and to take steps that will assure reasonable continuity of service where required.

In general, transmission lines can be repaired very quickly, since the trouble would be limited to a section or sections. The complete destruction of a major substation or generating plant would present a more difficult problem, with the power plant being the more serious. If either have only relatively minor damage, the restoration of these particular facilities may not require any undue length of time.

In the case of transmission and distribution lines, the utilities have had much experience in their restoration after severe storms--damage that would probably be far more severe than that due to bombing. Well-planned sabotage might, of course, result in greater damage.

In the case of lines, the men who daily meet such emergencies can get them back in service quickly if they have the necessary materials and equipment. Such material and equipment consist of conductor poles, hardware, and insulators. These are normally carried in utility stock and usually strategically placed throughout the system. Even if steel towers are destroyed, the line can be bypassed on wood poles until the tower can be repaired or replaced. All this is important and fortunate for us, because it will be these lines that will bring in the help to areas that may have lost their local source of power by bombing.

Substations, both at power plants and at load centers, consist of transformers and switching equipment, all installed or mounted within steel bays. Here again, if the substation is completely demolished, it may take a long time to replace it, although there is a good chance that service could be restored reasonably soon by bringing in spare equipment from another part of the system or from some other system.

In power plants certain spare parts are always carried in stock. Systems having several identical units, not necessarily in the same station, would normally carry one set of major spare parts, such as turbine and generator rotors. The type and magnitude of the damage to power plants will determine the time required to restore the plant. This could vary from a few hours to a complete rebuilding of the plant. In either case the interconnected system would have to be relied upon to make up the deficiency in generating capacity.

However, it is not unusual during peacetime for an entire plant to be lost on an interconnected system without loss of any load. I believe it is universally agreed that the best solution to the problem of protecting for the loss of power plants is by interconnection--sources of power from other plants. But this does not mean there will not be isolated cases that may be difficult to handle. There will be installations that pose specific problems, and in some cases the answer may be special equipment for emergency use.

In all these cases the importance of well-trained utility personnel, with the know-how for meeting emergencies, cannot be overemphasized. It is essential to full production that these people be left to this work should full mobilization take place.

Even more difficult may be the problem of coping with sabotage in time of stepped-up or all-out mobilization. All possible means need to be used to meet with any attempts at sabotage. But probably the most effective help can be given by the employees themselves. There is, I believe, no substitute that can compare with vigilance on the part of all employees. Elaborate lighting and guarding schemes can be very expensive, require extra help, and still not be too effective.

The utilities can do a great deal to assure continuity of service during emergencies. Most of the employees will be loyal and can be depended upon to be on the lookout for sabotage. By maintaining proper generating reserves and interconnections, they can be prepared to meet loss of generating facilities; and by giving attention to maintaining proper spare equipment and materials, facilities can be repaired promptly, as they have been.

As a further step for handling emergencies, some utilities make it standard practice to have large power transformers mounted on railroad cars or mobile trailers. These normally are of the universal type; that is, they will operate at many voltages and can therefore be used at many points on the system. On our own system we have quite a number of these. Since World War II we have added more of these mobile units.

There is, of course, a great deal in the way of spare equipment and materials located throughout one of these large interconnected groups of systems. During World War II some of the large interconnected systems had a list of all spare equipment and materials on all of these systems. They also cleared with defense and civil authorities as to what highways they could use to transport materials and equipment should this be necessary during or following an air raid. The utilities can and will do a great many things themselves. They should also cooperate to the fullest extent with governmental agencies on adopting sound plans for restoration of service.

In discussing the various means of mustering additional capacity, I did not include curtailment of load. This is for the reason that little can be gained unless curtailment is applied to industries consuming substantial amounts of energy. Little or nothing can be gained by brownouts or blackouts.

It seems to me that the argument that brownouts should at least be carried out for the psychological effect is weak. During all-out mobilization, homes are robbed to get sufficient help to achieve maximum production. Probably one of the best morale builders in such times is to let these people use electricity as they would normally. Actually the use can't increase substantially, because it will be very difficult to obtain new heavy energy-consuming devices at such times.

In summary, I believe that should we be faced with national emergency over the next few years, the utility industry would be in good position to meet the impact of the defense or war production. By using a portion of the then-existing reserves, by two- or three-shift operation in industrial plants, by making full use of all facilities of the large interconnected systems, and by such measures as nationwide daylight saving, the utilities should be in excellent shape to meet increased loads.

But, again, it is important to consider this as a means of meeting the initial impact, and to remember that a careful review must be made immediately to make sure that the expansion of power facilities is not reduced or stopped for any substantial length of time. During such periods it may take three years to get new capacity into operation. This, coupled with the fact that large amounts of critical materials are not required, makes it essential not to delay the necessary expansion.

If reasonable reserves can be maintained during all-out mobilization, there is the further advantage that it will be of great value in taking care of the snapback in the economy after the emergency. At the end of World War II, economists, both in Government and public life, predicted that industrial production would drop materially and the war peak would not be reached until 1948. In a great many systems this peak was reached in the fall of 1946, and the load has been growing ever since that time.

The next few years after the war were spent by all of the utilities trying to get reserves back to safe margins. On our own system, for example, during the peak season in the winter of 1948, we just met our load without any capacity to spare.

The problem was, of course, further complicated by the Korean War. But this again, I believe, points up the necessity for making sure that the power systems get the required amount of materials during periods of national emergency.

I thank you.

MR. HENKEL: Mr. Marquis is ready for your questions.

QUESTION: Mr. Marquis, I have two questions, and I would like to ask both at the same time. First, what is the relative difference between your thermal efficiency and your transmission efficiency of these overall hookups? The other is, what are you obtaining by charging premium rates to industrial customers during peak hours in order to cut the peak load down?

MR. MARQUIS: Let me see if I understand your question. I think the first is a question of efficiency.

QUESTION: What is the average transmission efficiency? You mentioned the average thermal efficiency as being 40 percent.

MR. MARQUIS: For the transmission only, the losses probably run around 5 percent. For any given system, the overall losses from power plant to consumer would be about 12 percent.

Now, the other was the idea of charging a premium over the peak in order to cut the use?

QUESTION: Yes. To reduce the peak demands by charging premium rates for the use of that power to industry during those peak hours.

MR. MARQUIS: You are talking now about in time of war?

QUESTION: Well, normal times.

MR. MARQUIS: On our own system we do not differentiate. For example, in the case of water heaters a great many systems have time clocks that keep them off the peak period. We have never done that. Any large amount of shifting would simply shift the peak to some other period of the day.

QUESTION: That is what I was trying to get at. That is what we have. They charge premium rates here in this area for industrial power during the peak hours. If you try to shift, it is a very difficult thing to do.

MR. MARQUIS: It is that.

QUESTION: You lose somewhere else. You have to pay overtime or shift workers around or something else.

MR. MARQUIS: Some systems have an offpeak rate. That is what you are thinking of. If all users took advantage of it, the peak would happen at maybe 3 A.M. instead of 11 A.M. I mean, if you want to distribute it so as to flatten it out, the way to do it is by tie-in, because the efficiency of generation over transmission would go up as you increase the load factor.

QUESTION: We tried to cut it during the peak hours of 11:30 to 9. I forget what the additional premium is during those hours for industrial customers. We found it very difficult to try to cut it down one bit between those hours.

MR. MARQUIS: I am not familiar with that rate. In our own case we don't have special rates for special times, except a limited amount of interruptible load. You can peak any time you want to.

QUESTION: It must be peculiar to this area.

MR. MARQUIS: It may be. I am just not familiar with that rate.

QUESTION: Mr. Marquis, with this happy family of various companies in the network, it would look like there would be some problem in seeing to it that each company gets its fair share of the business. You spoke about this system of automatic frequency regulation and its bias. Does it automatically more or less prorate the excess load among the various companies? That is to say, if the load were increased by 70 percent, does each company get its share of the 70 percent?

MR. MARQUIS: No. Not at all.

QUESTION: Would you comment on that?

MR. MARQUIS: Each system has its own load and customers. The purpose of this bias is to maintain whatever loads are set by contract between those companies and during emergencies allow additional power to flow over the line to the system in trouble. If one company is receiving power in excess of that scheduled from another over a tie line, it is usually because of an emergency, and usually he has a chance to reciprocate before many days pass. Do I have the question straight?

QUESTION: Well, I don't know exactly. Suppose you have a big breakdown in Florida and you don't have any power at all down there. There are a couple of million kilowatt-hours that somebody has to supply. It would be an advantage for each company in the tie-in to operate near 100 percent capability continuously, I assume.

MR. MARQUIS: That is right.

QUESTION: How do you prorate the business when this demand comes in?

MR. MARQUIS: We are speaking here of emergency conditions. To the extent possible all interconnecting companies will make their spare capacity available to the area in trouble. Neighboring companies have contracts covering the interchange of power during normal and abnormal conditions. Once the emergency is over, the power furnished to the system in trouble is billed to it in accordance with these agreements.

QUESTION: At one time they used to distribute direct current in New York City in one area. I presume they still do. Is direct current being distributed in any other place in the country? And what is the future of direct current in that little area in New York City?

MR. MARQUIS: Some of the major cities still do have some direct current service. I believe that in every case it is being gradually eliminated and before too long will be replaced by alternating current. On our own system I think we changed over the last about a year ago. In Charleston, West Virginia, it was very small.

QUESTION: What would you consider the maximum economic distance that you can transmit large blocks of power?

MR. MARQUIS: In this country that is dependent on the voltage at which you are prepared to transmit it. We are coming in this country to 330,000, or it may be 345,000, kv.

That is a difficult question to answer, because there are so many facets to it. There is no reason why you can't transmit up to 500 miles if there is reason for doing it. But there isn't a great deal of that, as you know, in this country. The Swedes are doing it, because their power sites are in the northern part of their country and the load is in the southern part some 600 miles distant.

I just don't believe it is possible to say that the answer is 200, 300, 400, or 500 miles unles you set up the boundary conditions.

QUESTION: The original cost of generation has an effect as well as the line losses?

MR. MARQUIS: That is right. However, I don't think 300 miles, for example, is unreasonable.

QUESTION: Does your company have a formal written recovery plan, for its recovery of production after damage, particularly enemy attack damage?

MR. MARQUIS: No we do not but in connection with transmission lines, for instance, we try to keep wood poles available in case we lose any of these steel towers. We had one case one time where a steel tower was dynamited. In this case we erected wood poles and by-passed the damaged tower until it could be replaced.

We have not lined up a plan that says: "If it happens at this point, here are exactly what steps we will take." I don't think it is possible to do too much of that ahead of time.

What you need is to make sure that adequate supplies of materials are on hand. Our people get a lot of experience, because they are frequently dealing with emergencies--storms and so forth. Those fellows will surprise you by what they can accomplish if given the materials to work with. Now, whether we should do more of that, I don't know. I would like to have your idea on that sometime.

QUESTION: Mr. Marquis, would you compare the relative transmission efficiency of high d. c. potential as opposed to a. c. potential in long-distance power transmission?

MR. MARQUIS: I can't give you any actual figures on it. With d. c. transmission more power could be transmitted over a given line than with a. c. transmission. However, the cost of terminal conversion equipment has so far made d. c. transmission unable to compete with a. c. There are many unsolved problems in the case of d. c. Further, there has been considerable progress made in a. c. transmission over the past few years.

QUESTION: On this frequency regulation, how do they keep their time together? Is that all tied together and then one of the interconnected systems operates that? Is it a simple operation, or do they follow up as they go along and keep their time correct?

MR. MARQUIS: I am sure there are no power systems that have as their main objective the furnishing of correct time. It is a byproduct of the close frequency held on most systems. What they do on these large interconnected systems is to correct time occasionally--usually during offpeak hours of the day. But the time seldom gets off more than a few seconds.

Occasionally two systems will be split apart during an emergency. What they normally do is go back together just as fast as they can but this might leave one system two or three seconds out, and the other right on time. Later they pick an opportune time, separate the systems--each get on time then go back into parallel. But we are always careful not to leave the impression that we are running a power system to keep clocks on time.

QUESTION: Mr. Marquis, you indicated that daylight saving will save a great deal of power, but that brownouts are useless. If brownouts are useless, then how does daylight saving help save a great deal of power?

MR. MARQUIS: Daylight saving reduces the peak load because certain evening loads overlap during the evening hours with standard time. Daylight saving reduces this with substantial reduction in the peak load. It saves little in the way of kilowatt-hours, but it does save capacity. On the other hand brownouts save little either in capacity (kilowatt) or in energy (kwh). It gets to the point of whether it is believed desirable to brownout to cause people to realize that there is an emergency going on.

MR. HENKEL: Mr. Marquis, I am sure we all have a better understanding of some of the problems of this particular industry. On behalf of the Commandant, I thank you for giving us such a constructive and informative talk. Thank you.

(24 Feb 1955--750)S/sgh