# War Problems of Electric Utility Engineers

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THE increased demands for electric power created by war industries and the parallel scarcity of critical materials and manufacturing facilities for making generators, transformers, and wire needed in a corresponding expansion of utility systems have imposed severe operating problems on electric utilities. The increase in use of electric energy is illustrated in *Fig. 1,* where the total annual generation of energy in the states of Arizona, California, and Nevada has been plotted, beginning with 1900. Actual statistics are not yet available for the year 1944 but current records permit the estimate of approximately 23 billion kilowatt-hours generated in these states in 1944. The output in 1941 was 14.4 billion kilowatt-hours, which means that energy use since Pearl Harbor has increased 60 per cent.

## INTEGRATED OPERATION

Early in 1942 it became apparent that the materials required for United States participation in the war and the production of equipment for the Allied countries were causing a critical shortage of certain materials. The War Production Board was given the task of conserving critical war materials. At the same time the Pacific southwest area faced an increased electrical demand of approximately one million kilowatts of new war load, consisting of the production of electrolytic aluminum and magnesium, steel, synthetic rubber, airplanes, ships, and high octane gasoline, and for military camps, new housing, and miscellaneous small industries. Preliminary studies indicated that if the generating capacity scheduled for installation by utilities serving the area was deferred because of the critical material and manpower situation, the Pacific southwest would become one of the most critical power regions in the United States. Accordingly, J. A. Krug and V. M. Marquis, officials of the Power Branch of the War Production Board, came to southern California to study the problem. A meeting of utility executives was called by Mr. Krug. A program based on full integrated operation of all electric utilities was outlined which would assure continuous electric service to the war industries and still permit the deferment of 715,000 kilowatts of generating capacity then scheduled for installation. This program was agreed upon by all utilities.

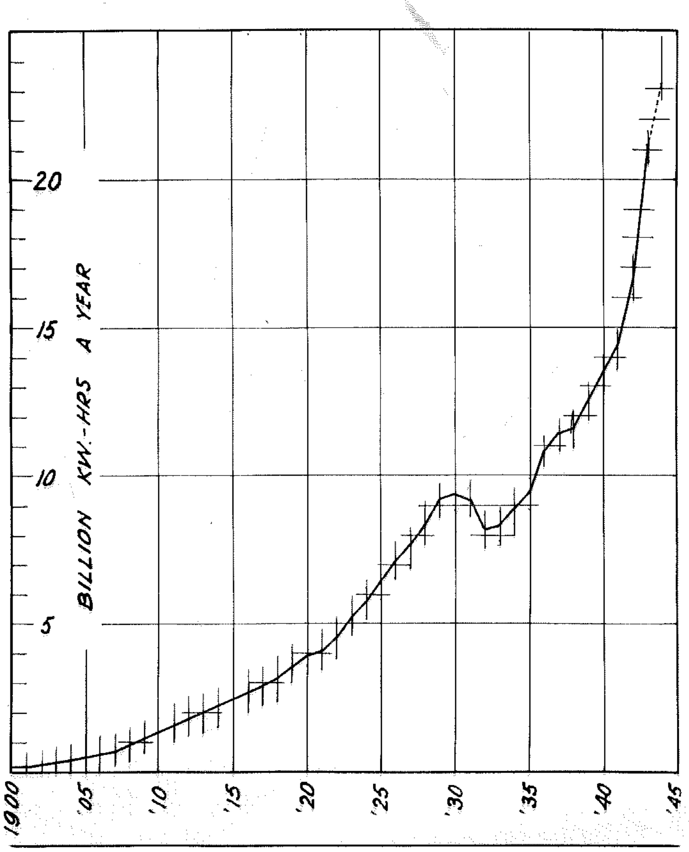


FIG. 1. Annual generation of energy in the states of Arizona, California, and Nevada.

A committee was organized in May, 1942, consisting of engineers familiar with operating problems and representing all utilities in the area. The first task of the committee was to make a study of the resources and loads of all utilities in the area. In general this was accomplished by having a representative of each utility submit the load and resource estimates for his system to Southern California Edison Company's engineers, who compiled the information on an area-wide basis. Copies of the completed tabulation were distributed to the War Production Board and the several utilities for final analysis. The completed studies were analyzed as to estimated load growth, adequacy of generating capacity, and adequacy of interconnections with neighboring utilities. A study of contractual arrangements between adjacent utilities was made to ascertain their adequacy for maximum interchange of power.

Upon completion of the load and resource studies an analysis of system facilities was made for the entire area, which now consists of all of California and practically all of Arizona and Nevada, with the object of charting an operating program which would assure adequate resources to carry the wartime loads of every utility in the area with a minimum use of strategic materials. Recommendations were made for additional generating capacity and for increased interchange capacity only where unavoidable. It was the further objective to operate the entire area on an integrated basis in order to assure a minimum use of critical fuel oil. After completion, the original studies were continually kept up to date in accordance with changes in load estimates and hydrological conditions.

Under the guidance of the committee all the interconnected generating facilities in the area have operated as an integrated single system in order to insure the maximum use of water power and to save fuel oil. The increased interchange of power among utilities has saved critical materials which would have been required for construction of new generating equipment. Since the new loads totalling approximately one million kilowatts were added, the generating capacity has been increased by only 550,000 kilowatts, excluding the 90,000 kilowatt generator which was released for operation at Boulder Dam on November 1, 1944. The present-day generating capacity in the area is approximately 4,590,000 kilowatts.

## TIME CHANGE A FACTOR

In the states of Arizona, California, and Nevada the sales of electric energy nearly doubled between 1939

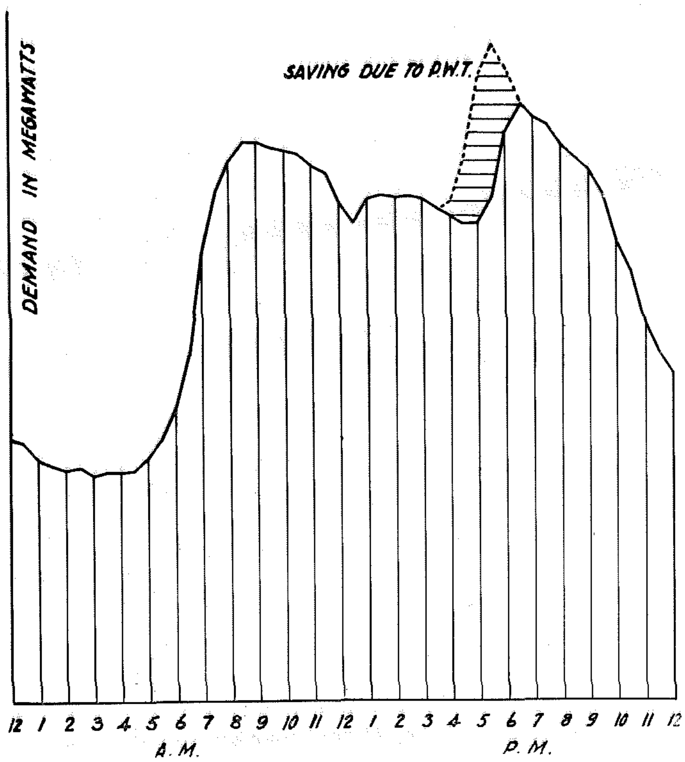


**FIG. 2. Typical winter day load curve of an electric utility showing the estimated effect of change from Standard to War Time.**

and 1944. This increase, however, was handled by an increase of only 25 per cent in generating capacity. Such a record was possible only through the close cooperation and integrated operation of all electric properties. The utilities have been greatly assisted in the effort to supply energy to the growing load at a minimum of new generating installations by the change from Standard Time to War Time. The effects of the change cannot be accurately evaluated but a reasonable estimate shows that the peak demands of utilities have been reduced by approximately 10 per cent. *Fig. 2* shows a typical winter-day load curve of the Southern California Edison Company and the estimated saving in demand due to Pacific War Time. The reduction in demand may have saved the installation in the Pacific southwest of generating capacity to the amount of some 250,000 kilowatts and the installation of distribution transformer capacity in residential areas that is even more difficult to evaluate.

## GAS, OIL, AND WATER INTEGRATED

In January, 1944, it became apparent that the water resources of California and the Colorado River would be subnormal for the year, necessitating a large consumption of critical fuel oil to cover the deficiency. A meeting was arranged in February, bringing together the electric utilities, oil and gas companies, the War Production Board, and the Petroleum Administration for War. As a result of a cooperative program worked out at this meeting, fuel oil use for power has been cut by about 50 per cent. The Southern California Edison Company steam plants have in effect operated as a regulating valve for southern California gas systems, increasing and decreasing load to enable the gas transmission lines to operate at full capacity at all times. This has made it possible to operate oil wells at full output continuously without wasting gas. Thus to cooperation among individual electric utilities was added cooperation with oil companies and gas utilities.

The accomplishments of the cooperative efforts under the direction of the committee can be summed up as follows:

1. Integrated operations have saved critical war materials which would otherwise have been required for additional generating equipment and transmission lines.

2. Fuel oil was saved by the use of all water power resources in the whole area in lieu of power generated by fuel oil.

3. Additional savings in fuel oil were achieved by the use of surplus gas fuel regardless of its location in the area.

## UPRATING OF EQUIPMENT

In the field of transmission and transformation utility engineers faced the same conditions, *i.e.*, increasing currents and restrictions on material. The practice of uprating equipment has been widely followed throughout the country as a wartime measure. The current-carrying capacity of overhead line conductors in the past has been based on a 40 degree Centigrade rise above ambient in still air. Experiments showed that slight air movements such as two feet per second lower the temperature of conductors considerably and allow them to carry more current for the same temperature rise. For example, a 4/0 stranded copper conductor would carry 360 amperes in still air and 450 amperes with a two-foot-per-second air movement around it with the same temperature rise. It has been very seldom, however, that the capacity of overhead lines has been limited by the current-carrying capacity of the conductors. The limitation has been as a rule the more or less arbitrary standard of voltage regulation. The war emergency has compelled utility engineers to sacrifice some of the high standards set for voltage regulation of transmission and distribution lines in order to carry the added load on existing lines.

On existing self-cooled transformers it is possible in practically all cases to obtain an increase of 25 to 33 1/3 per cent in capacity by the application of fans or blowers for forced-air cooling. This, however, as in the case of overhead transmission lines is obtained at the expense of voltage regulation and for this reason has been limited in practice. The past practice of the Southern California Edison Company in installing large power transformer banks has been that of installing four transformers, three of them in a bank and the fourth as a spare. When load required additional capacity at the same location, two new transformers would be purchased and banked with the spare one to make a second bank. During the war emergency the spare transformers scattered among the various substations enabled the company to furnish service to new plants and military loads without delay by combining three spare transformers of similar characteristics removed from different locations into an active bank serving the new load.

In a number of cases it has been possible to shift or to exchange transformer banks between lightly loaded and overloaded substations and thereby to put idle transformer capacity to work. Approximately 100,000 *kva* of transformers have been shifted on the lines of the Southern California Edison Company in order to load them up. In some cases as many as three or four substitutions were made to release additional capacity. As an example, a new 75 *kva* transformer would displace a lightly loaded 150 *kva* transformer. The latter would in turn be substituted for a lightly loaded 250 *kva* transformer, releasing it for service to a new load. A program of this sort involves much careful study of detail, of load records over long periods of time, and of prospective load increases in all locations involved, but as in the case of integrated operation of generating facilities it has resulted in the carrying of increased loads with the addition of transformers equal to but a small fraction of the increase in load.

Among problems created by scarcity of critical materials the substitution of iron wire for copper and wood for structural steel should be mentioned. The substitution of iron wire for copper is highly unsatisfactory, since the resistance of iron wire is in the order of 10 times for the same size of copper wire. Fortunately the crisis in copper production was overcome before any extensive installations of iron wire had to be made. A number of substations were built, using lumber in place of structural steel. During the last year, however, the situation has been reversed and lumber has become more critical than steel.

## LEND LEASE AND REPLACEMENT

Late in 1942 the procurement division of the United States Treasury Department requisitioned two 42,500-kilowatt 50-cycle turbine generators from the Long Beach steam plant of the company for lend-lease shipment to one of the United Nations. This nation had suffered so heavily in production capacity as a result of the loss of a large power development that relief was considered necessary in less time than would be required for the manufacture of new machines. Under existing conditions, earliest possible replacement of the requisitioned generators was highly important from the standpoint of the Southern California Edison Company as well as the Pacific southwest area. With the excellent cooperation of all interested parties, including the W.P.B., replacement has been effected in record time. The work of removing two units and replacing them required a total of approximately 10 months from the time the first turbine was posted by the government representatives to the time of admitting first steam to the new machine.

The requisitioned equipment, and hence the equipment that it was necessary to replace, comprised the turbine and generator, condenser, and all auxiliary equipment from the main steam header to the boiler feed pumps, with the exception of the circulating pumps and piping. The latter pumps were not taken with the units because their head characteristics did not conform to the requirements of the foreign station site.

Representatives of the Office of War Utilities, W.P.B., offered lists of available equipment. Included was information that manufacture of an 80,000-kilowatt machine had been undertaken for a Midwest utility as part of an expansion program that had recently been canceled. Investigation developed that although this machine had been designed for 850 *p.s.i.*, 900 degrees Fahrenheit, manufacture had only been started, and the machine could still be adapted to Long Beach steam conditions. To adapt the original design to 375 *p.s.i.*, 700 degrees Fahrenheit steam conditions, the manufacturer increased turbine steam-admission areas and provided two steam supply lines.

Each of the two generator windings has been connected to a separate 39,000 *kva* transformer bank remaining from the original installation. The generator is totally enclosed and equipped with self-contained heat exchangers, permitting the use of hydrogen as a cooling medium and condensate as a coolant. The direct connected exciter is air cooled.

Because of the short time and production schedules, Allis Chalmers Company built the condenser to C. H. Wheeler Company design, originally prepared for the unit when on order for the Midwest location, the latter company cooperating by releasing its drawings. Most of the auxiliary system was assembled from leftovers, from secondhand material taken from existing piping in the plant wherever it could be spared, and partially fabricated material for canceled projects. The condensate pumps and air-removal equipment were manufactured by Allis Chalmers. The job is an example of tailoring the feed-heating cycle to fit available equipment. The engineers did this satisfactorily and, with the aid of the W.P.B., obtained and installed all necessary equipment for initial operation with the turbine.

## SECURITY

In addition to the major problem of meeting increased load demands in the face of shortage in new facilities there were a number of other problems created by war conditions. A few of these deserve brief mention. War conditions introduced new hazards to operation such as possible sabotage, barrage balloons breaking loose from their moorings and pulling their cables across transmission lines, airplanes out of control contacting transmission lines, target-towing cables falling into transmission lines, etc. Since electric power-supply is an essential element in war production, the safeguarding of generating and transmitting properties of all utilities was a matter of concern not only to the utilities themselves but to the Army, Navy, law enforcement agencies, and regulatory commissions. A high degree of cooperation was maintained with the above agencies. Telephone installations and line extensions were made from the company's private communication system to Army, Navy and civilian defense headquarters. Installations were made for street-light blackout controls, and, in addition, the Army has been permitted to use company poles and in some cases company telephone lines for communication between guard posts. Installations were made for bomb splinter protection at key stations. Oil level alarms on outdoor transformers, fences, etc., were installed for sabotage protection. The company hired, trained, and installed armed guards at major stations on the system to augment the military guard. The utility repair corps was organized and equipped with gas masks, steel helmets, decontamination units, and pumps. Some 363 automobiles and trucks were equipped with approved blackout lights for this service. Men were trained in bomb reconnaissance and decontamination of war gases and were in a position to handle this type of emergency work. In 1944 the Southern California Edison Company received the National Security Award for the maintenance of a superior standard of protection and security.

In concluding this brief outline of war problems of electric utility engineers, not the spectacular job of developing radar, rockets, etc., but still a big job that had to be done, the author quotes from an address by J. A. Krug to T.V.A. distributors at Chattanooga, Tennessee, on February 16, 1943: "The power men—public and private, in this area and throughout the country—should be proud of the job that has been done in providing power supply. Power has never been 'too little, or too late.' There is today no shortage of power. This is in sharp contrast to the situation as to many other vital necessities. I do not know of a single instance in which the operation of a plant has been delayed by lack of electric power supply. . . . I repeat, the power men of the country can be proud of the job that they are doing."