Presented at the Pacific Coast Convention of the American Institute of Electrical Engineers, Los Angeles, Cal., September 18–20, 1919.

CALIFORNIA 220,000-VOLT — 1100-MILE — 1,500,000-KW. TRANSMISSION BUS

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ABSTRACT OF PAPER

This paper summarizes the power resources of California and the probable loads to be supplied within the next six or seven years. For the purpose of economically distributing the necessary power and supplying the load, a long high-voltage transmission line is proposed. As this line would interconnect a number of different companies, it assumes the nature of a bus bar. The authors show how the proposed line may link with some of the lines now in service and enumerate the advantages of such interconnection. A comparison is made between the 240-mile Big Creek line now operating at 150,000 volts, 50 cycles, and the operation of this line at 220,000 volts, 60 cycles. Operating data on the Big Creek line are shown to indicate the character of the construction necessary for California conditions. Conclusions are drawn as to the particular features to be observed for successful operation of 220,000-volt lines.

INTRODUCTION

FUELS, particularly oil, must soon be used for isolated power only in places where electric power is not available, as in the propelling of air and ocean craft. In large power systems, especially in the West, the use must be limited to standby service, for peak loads, low water periods, and other emergencies.

POWER RESOURCES

California has available ample hydroelectric power to supply the industrial and agricultural demand for many years.

Small developments aggregating 325,000 kw. have been completed and many others of this type are available. There are also four large projects as indicated in Table I. which can readily be developed to a capacity of 1,500,000 kw. in the near future.

The data for the following tables of resources and loads, of the Northern part of the state, are taken from various reports which have been published and no attempt has been made to verify them.

TABLE I—LARGE POWER RESOURCES

	Now Developed and Under Construction	Proposed Developments 1926	Reasonable Future Development (Not Ultimate Capacity)
	kw.	kw.	kw.
Pitt River..................	None	200,000	500,000
Feather River...............	100,000	200,000	300,000
Big Creek..................	100,000	300,000	500,000
Colorado River..............	None	None	200,000
Total..................	200,000	700,000	1,500,000

Total 1926 hydroelectric power development including small projects is 1,025,000 kw.

Load Demand

The best available information indicates a demand in 1926 approximately as shown in Table II.

TABLE II.

1.	Sacramento Valley, northern portion..........................	70,000 kw.
2.	Truckee River electrification................................	40,000 "
3.	Sacramento Valley, southern portion..........................	125,000 "
4.	San Francisco Bay District...................................	250,000 "
5.	Fresno District..	90,000 "
6.	Bakersfield District, including Tehachapi electrification...........	125,000 "
7.	Los Angeles District...	300,000 "
8.	Barstow and Needles District, including railroad electrification....	40,000 "
	Making a total of..	1,040,000 "

In order to carry this load, approximately 500,000 kw. additional in hydroelectric capacity will be required.

A demand for power such as shown in Table II can be supplied most economically by power developed in large units. Large power units require transmission lines of the highest possible economic voltage.

*It has been shown that, for long transmission, 220,000 volts is economical under conditions which require a much more expensive construction than has proven adequate for the 150,000-volt lines of the Southern California Edison Company.

*Silver, *Problems of 220-kv. Power Transmission*, page 1037.

CALIFORNIA TRANSMISSION BUS

On this basis, a plan as shown on the map, Fig. 1, is proposed. In this plan the interconnection of all the California Power Companies has been assumed, as an economic necessity for

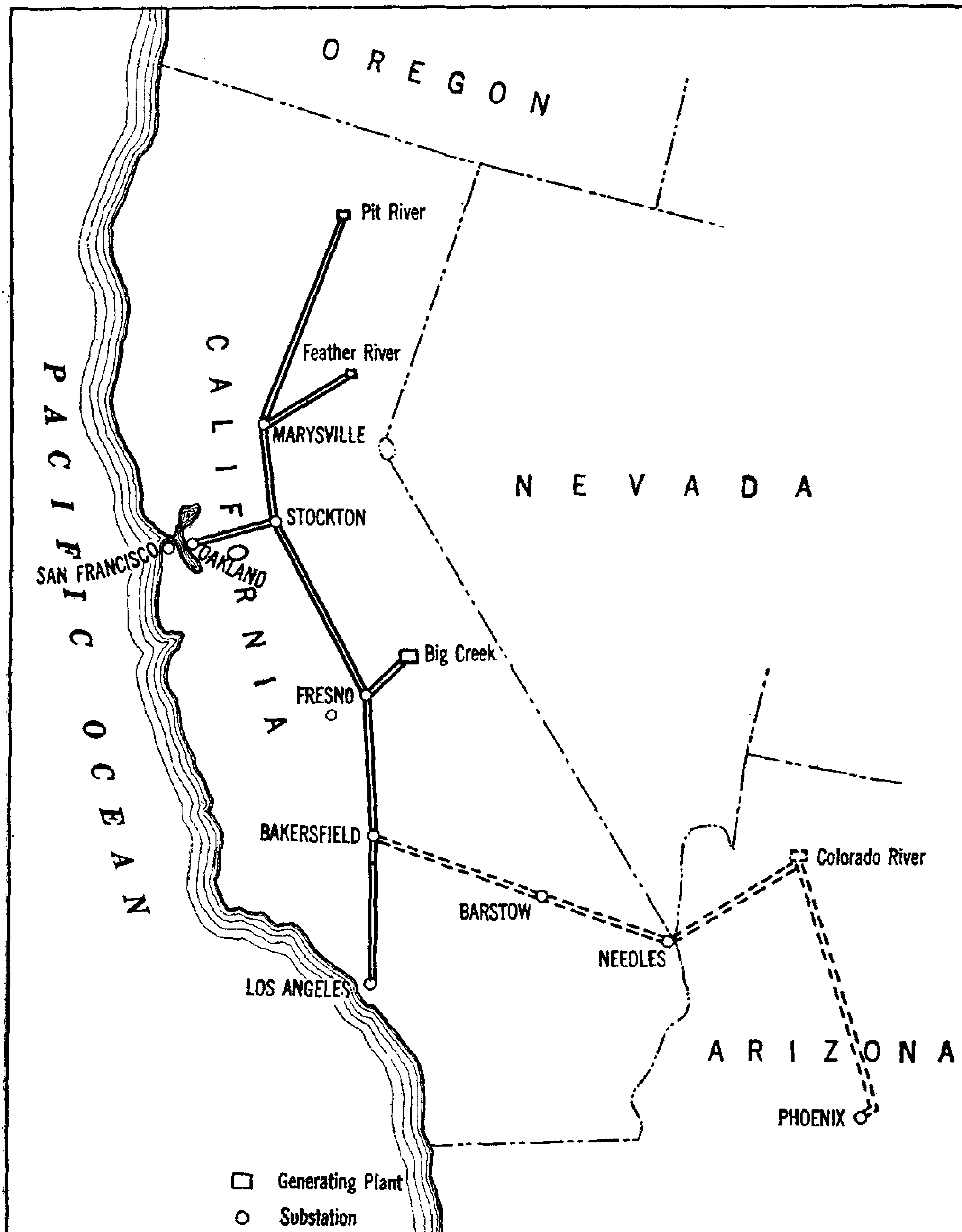

FIG. 1—CALIFORNIA 1100-MILE—220 KILOVOLT—TRANSMISSION BUS

its best utilization. Interconnections of limited capacity are not entirely satisfactory because they fail just at the time they are needed most to transfer from one system to another large blocks of power.

The plan of the proposed scheme involves the construction of a two-circuit transmission system extending from Pitt River to Los Angeles, a distance of 570 miles. Branch lines of like voltage connect the three other power projects and the San Francisco load center to this main line on which the other load centers are located. The main line thus becomes a high-tension bus extending nearly the entire length of the state, hence its name; California Transmission Bus. This arrangement makes possible unlimited interconnection and exchange between all the power companies of the state.

Substations have been located at Marysville, Stockton, San Francisco, Fresno, Bakersfield and Los Angeles. These points are natural load centers and suitable points for connecting with the present power systems. On the Colorado River branch, the construction of which is dependent upon the electrification of the transcontinental railroads, substations would probably be located at Barstow and Needles. The substations divide the lines into sections of suitable length for practical operation, the longest section being 150 miles, as shown in Table III.

TABLE III.

Pitt River to Marysville	150 miles
Feather River to Marysville	60 "
Marysville to Stockton	90 "
Stockton to San Francisco	60 "
Stockton to Fresno	130 "
Big Creek to Fresno	40 "
Fresno to Bakersfield	100 "
Bakersfield to Los Angeles	100 "
Bakersfield to Barstow	110 "
Barstow to Needles	150 "
Needles to Colorado River	100 "
Colorado River to Phoenix	100 "
Pitt River to San Francisco	300 miles
Big Creek to Los Angeles	240 "
Big Creek to San Francisco	230 "

THE TRANSMISSION LINE

The standard frequency, 60 cycles, has been assumed on the basis that the Southern California power systems operating at 50 cycles will ultimately find it advantageous to conform to the A. I. E. E. standard. In the natural growth of the load as shown in Table II, 70 per cent of the 1926 load will be supplied by the 60-cycle systems. Interconnection of such large load centers or power sources through frequency changers, limits the exchange of power, is uneconomical, and increases tremendously the required operating vigilance.

The practicability of the high-voltage line has been well demonstrated by over five years of remarkably successful operation of the 150,000-volt lines of the Southern California Edison Company which, during this period have delivered from the Big Creek power houses over the 240-mile lines to the Los Angeles distribution system, 1,200,000,000 kw-hr. at an average efficiency of 87.5 per cent with a 45 per cent load factor. During this period there have been no interruptions for which the high voltage is responsible, and on the contrary, the system has been free from disturbance and interruption to a greater degree than the lower voltage lines in the same locality.

The present Big Creek lines can be operated at 220,000 volts, 60 cycles, without material change and this is proposed as a link of the transmission bus, and its operation under these conditions will be analyzed and applied to conditions of the proposed system.

Corona. As now operated, at 150,000 volts and 50 cycles, the voltage is only 80 per cent of the lowest critical voltage of any part of the line and there is no corona loss. At 220,000 volts, 60 cycles, corona loss occurs to some extent on the entire line but amounts to but 0.4 per cent of the line capacity during fair weather. With storm conditions over the entire line, and with an assumed reduction of 20 per cent in the critical voltage, the corona loss would be 8 per cent of the line capacity. This loss is not sufficient to make the line inoperative and would occur too rarely to be an economic factor.

Insulation. The Big Creek 150,000-volt lines have nine units in each suspension string and two eleven-unit strings in parallel on dead ends. During the five and one-half years of operation only two insulator string failures have occurred. Both of these were during normal conditions of operation without any apparent cause, other than that of being in a location where the insulators have been found to have a relatively high rate of deterioration.

The Big Creek line towers allow sufficient clearance to permit the lengthening of the nine unit suspension strings to eleven units, and to any desired number of units at dead ends. Table IV. shows safety factors for insulator strings, wet and dry.

The Big Creek line operated at 220,000 volts is at the critical corona voltage and any disturbances resulting in a higher voltage will quickly expend their energy in producing corona loss, which will permit a smaller safety factor to be used.

The curves in Fig. 2, showing arc-over voltage as reproduced from Mr. Silver's paper, *Problems of 220-kv. Power Transmission,* show no practical gain in dry arc-over voltage for strings of more than ten units, and with these facts in view it is proposed that for operating the Big Creek line at 220,000 volts, suspension strings have eleven units and dead end strings 12 units in series. Insulator testing crews have several times reported four and five defective units in a nine-unit suspension string, without any indication of trouble. The only apparent value of a longer string than that proposed would be a decreased probability of sufficient defective units in a string to cause breakdown. Developments of methods of grading insulator units and shielding insulator strings, will in all probability, materially change curves of Fig. 2.

Present day method of insulator testing and maintenance

TABLE IV. SAFETY FACTORS FOR INSULATOR STRINGS

	Wet arc-over		Dry arc-over	
	9 unit String	11 unit String	9 unit String	11 unit String
(87 kv. to ground) 150 kv........	4.3		4.8	
(127 kv. to ground) 220 kv.......		3.7	3.3	3.4

would probably have prevented the two failures which have occurred on the Big Creek lines as previously mentioned. These methods applied to the lines operating at 220,000 volts and the use of the better types of insulators now available will insure successful operation.

Charging Current. Long high-voltage lines cannot be operated without synchronous condensers at the receiving station to regulate the voltage, and as a consequence the charging current, even at the standard 60-cycle frequency becomes a factor of no great importance as long as these synchronous condensers are connected to the line.

Without these condensers the line charging current must be furnished entirely by the generators, in which case the generators may become greatly overloaded and at the same time produce a very high voltage over which the operator has no control. To avoid this emergency a transmission line with its generators, transformers, and synchronous condenser must be considered as a unit and as such should be securely coupled together electrically at all times. This has been proved praccal in the case of the Big Creek system in which it is possible to start the 15,000 kv-a. condensers and bring them up to speed with the generators.

Line Capacity. The Big Creek lines as operated at 150,000 volts with 30,000 kv-a. condenser capacity per line at the receiver end are each good for 57,500 kw. at 85 per cent power factor and will have under these conditions a line drop of 11 per cent.

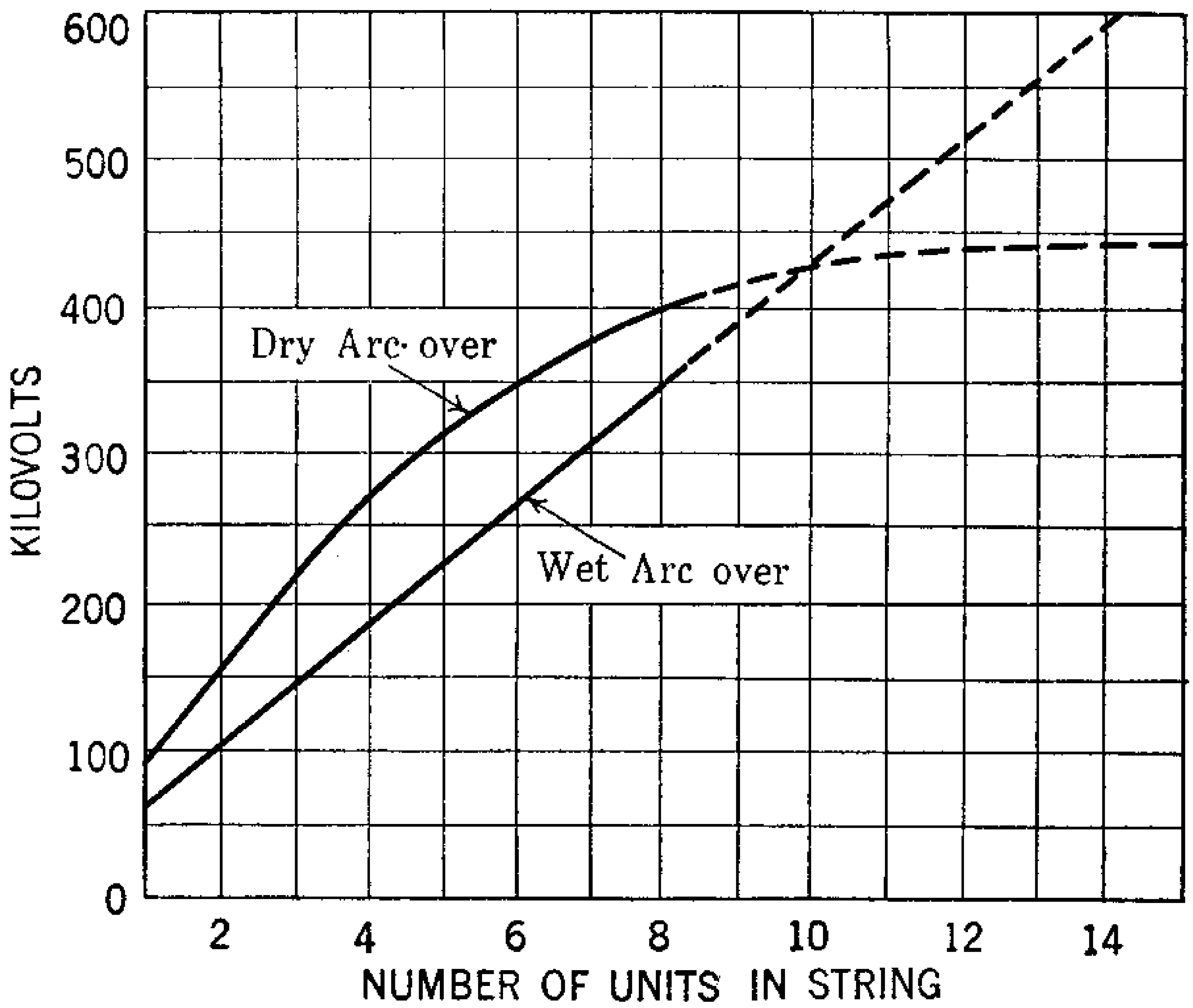

Fig. 2—Typical 60-Cycle Arc-Over Characteristics of Suspension Insulators

Operated at 220,000 volts these lines should each have a capacity of 125,000 kw. with an equal line drop when provided with the proper condenser capacity, which is approximately 75 per cent of the line capacity in kilowatts.

This is a fair indication of the conditions which will exist in the proposed system, the load centers of which are so distributed as to limit the actual average distance of transmission to about 200 miles. The economic gain in doubling the capacity of lines which cost approximately $6,000,000, the present cost of which would be at least 30 per cent more, would more than offset the cost of all necessary changes, including the adoption of the standard frequency.

Mechanical. The type of construction used on the Big Creek line has proven entirely adequate for California conditions. There have been only three mechanical failures all of which occurred shortly after the line went into service and were all due to defective line hardware. In one case the failure was due to faulty design. This fault was entirely corrected by redesigning the cable clamp so as to grip the steel core independently of the aluminum conductor. The other two were due to individual defects in parts. There have been no tower failures and no tower maintenance whatever has been required. Approximately 20 per cent of the Big Creek line is subject to ice and snow conditions, parts of it reaching altitudes of 5000 feet. Similar conditions exist over practically the entire proposed 220,000-volt system.

Operation. The most interesting feature of the operation of the Big Creek system is its reliability, which has been equal to that of steam plants of similar capacity located near load centers. Flashovers have caused only momentary interruptions and have in no case resulted in damage such as to prevent immediate resumption of service. During the greater part of the time the power has been carried over a single line for a large part of the distance.

The operating history of the Big Creek system discloses no evidence of any trouble due to the high voltage of the system, and in addition has demonstrated that higher voltages may be used with equal or greater reliability. The Big Creek 17,500 kv-a. generators have operated at 60 cycles satisfactorily and delivered full output at this frequency.

High-tension line switching and synchronizing has been carried on consistently throughout the operation of the Big Creek system without trouble, and should be possible on the 220,000-volt system. During times of switching, slight discharges, never followed by any energy current, occur on the arresters. Operating at corona voltage rather than at 80 per cent of the critical voltage it may be possible to absorb these disturbances without arresters.

Complete parallel operation of all lines must be adhered to in the proposed system. Satisfactory protective relay systems for dropping defective sections with little disturbance have been developed for present parallel transmission lines and there appear to be no obstacles to extending these to the higher voltages.

Generators. Curves of Figs. 3 and 4 show generator and line characteristics for 60-cycle, 220,000-volt systems. The full lines are the charging currents in amperes for different lengths of line plotted against per cent normal voltage. The broken lines are generator characteristics of various sizes of generators when connected to condensive loads with no field excitation. The point of intersection of the generator curves with the line

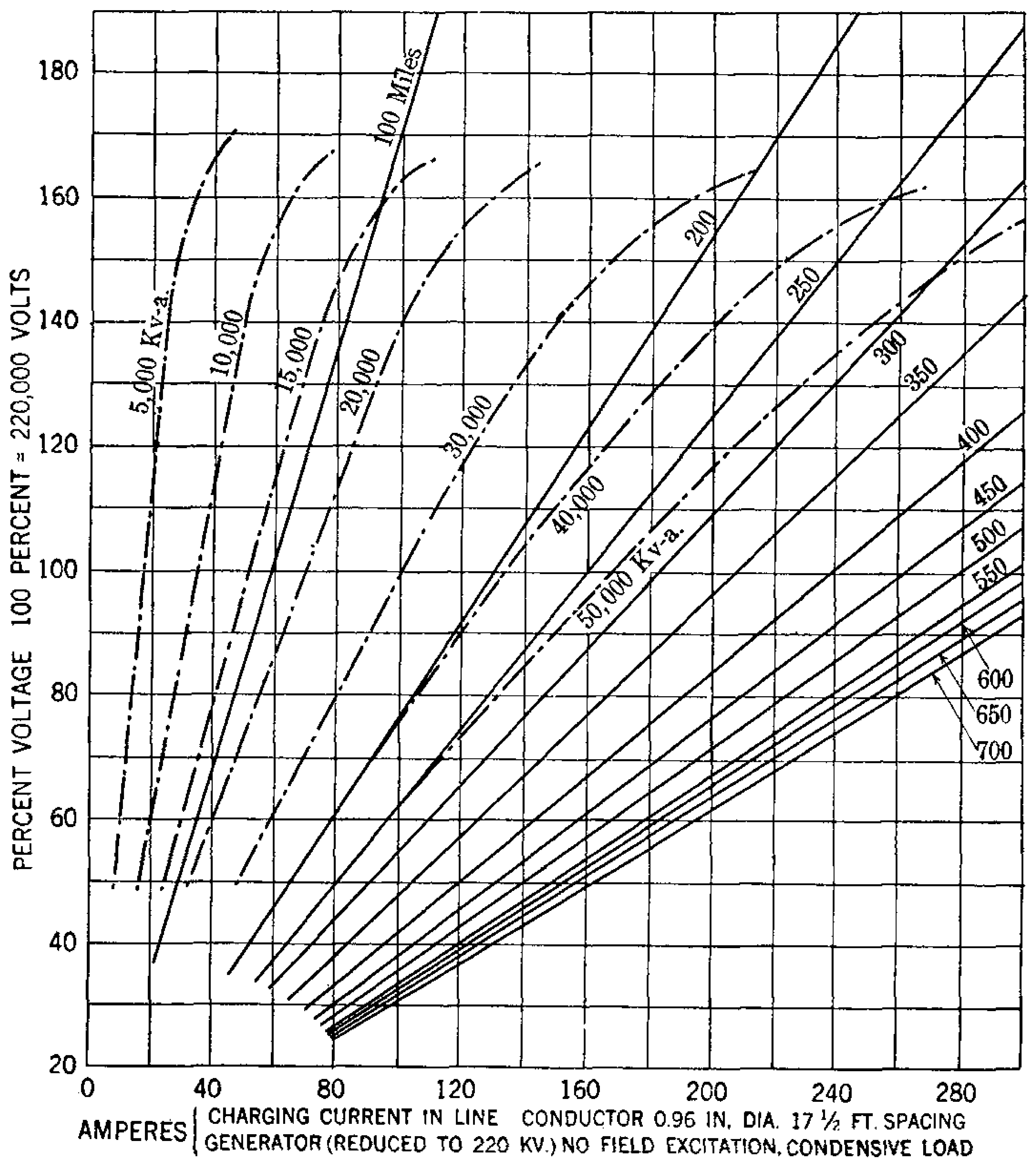

FIG. 3—GENERATOR AND LINE CHARACTERISTICS—60 CYCLES—220,000-VOLTS—GENERATORS WITH SHORT-CIRCUIT RATIO 1.0

charging current curve for any particular length of line determines the voltage to which the generator will build up when connected to that length of line with no field excitation. Fig. 3 is for generators with a short-circuit ratio of 1.0, while Fig. 4 is for those with a ratio of 1.5.

Fig. 3 shows that with 50,000 kv-a. of generating capacity connected to a line of 250 miles, the line can be charged without losing control of the voltage with generators of this design. By having synchronous condensers connected to the line at the receiving station generators of this capacity will bring up any length of line necessary to the successful operation of the proposed system. These curves show that generators for such a system should be designed with the highest short-circuit ratio

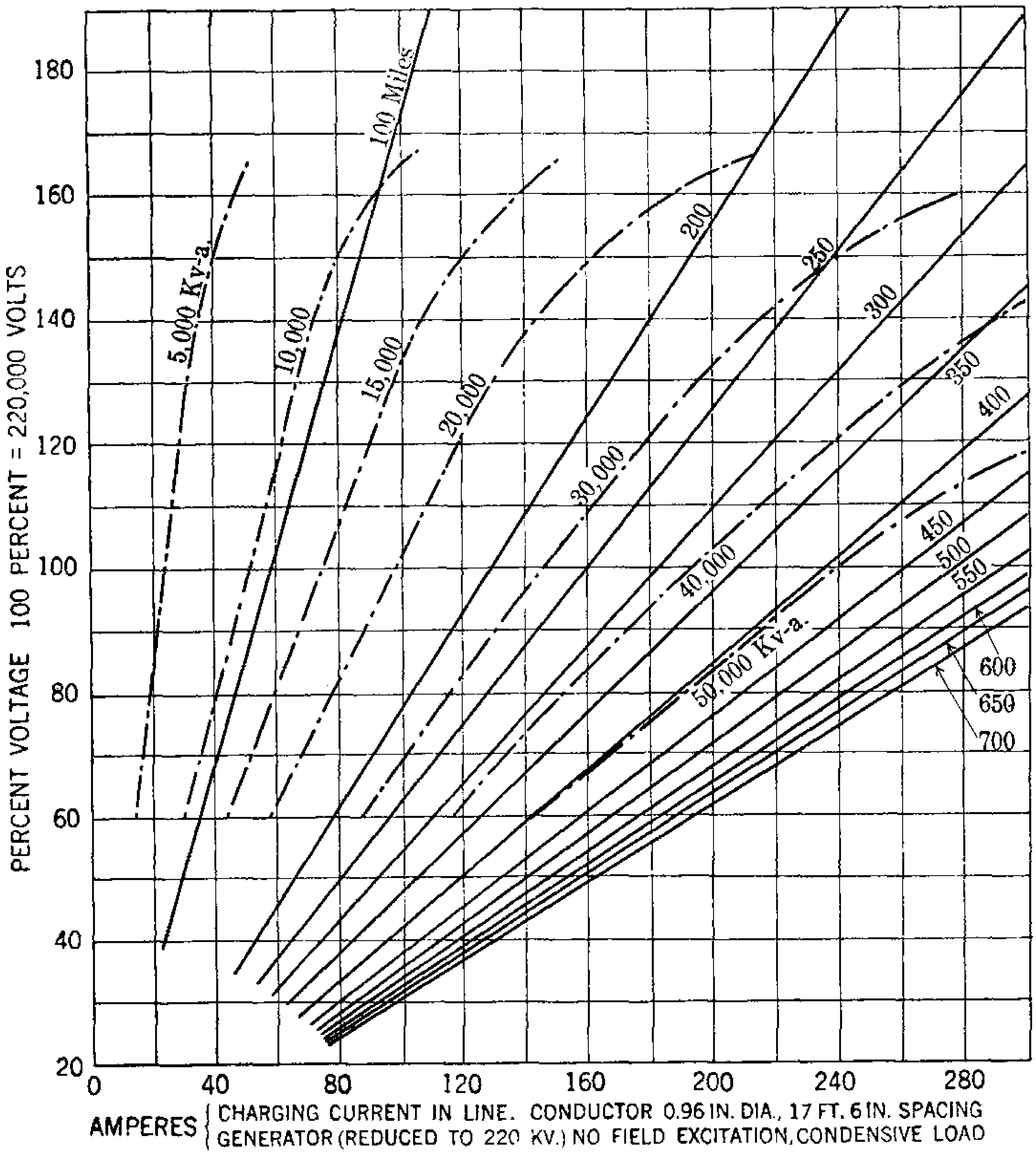

Fig. 4—Generator and Line Characteristics—60 Cycles—220,000 Volts—Generators with Short-Circuit Ratio 1.5

that other conditions will permit in order to reduce to a minimum the tendency to become self exciting.

*Data for these curves were worked out in the laboratory of Throop College of Technology in 1915 and results verified by actual tests on the 17,500 kv-a. generators at Big Creek.

*For further data and explanation of generator performance with large condensive loads see Newbury, *Electric Journal*, 1918.

Conclusions. Such a system as proposed is needed immediately; all engineering fundamentals essential to a solution of its problems are well understood and the Big Creek system

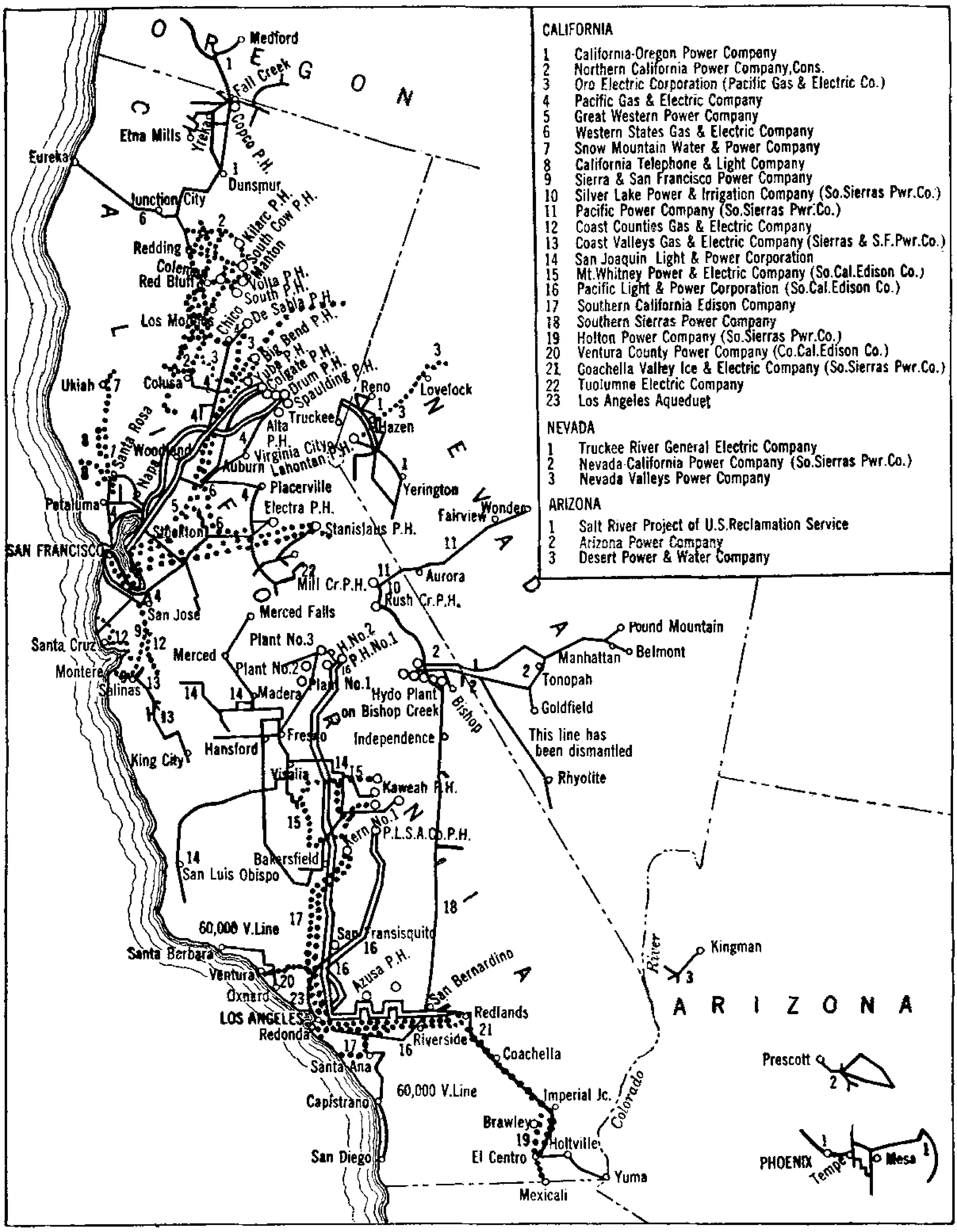

FIG. 5—MAP OF WESTERN TRANSMISSION LINES

can be used as a part of the project without material reconstruction.

To supply this need, arrangements should be made without delay for a complete working out of all details of the proposed system, as otherwise in the future it may be necessary to do a large amount of reconstruction to bring together individually-designed systems, which is never a wholly satisfactory procedure.

COMPARATIVE DATA

	Big Creek lines at 150 kv.	220 kv. lines as proposed by Silver
Aluminum steel cable		
Diameter	0.95 in.	1.036 in.
Circular mils	683,000	808,900
Weight per foot	0.75 lb.	0.94 lb.
Length of average span	750 ft.	800 ft.
Weight of towers without footings		
Suspension	4300 lb.	9000 to 14,000 lbs.
Anchor	6450 lb.	24,000 lb.
Stringing tension at 80 deg. fahr.		
No ice allowance	4740 lb.	
Ice allowance	3130 lb.	
Maximum tension allowed	8500 lb.	17,300 lb.
Insulator strings to carry load		
Suspension	1	2 and 3
Anchor	2	6

For further data regarding the Big Creek line refer to the paper 150,000 *Transmission System* by Woodbury, A. I. E. E. TRANS., 1914.

Map. Fig. 5 shows the existing transmission systems of California, Nevada, and Arizona, varying in voltage up to 150,000 and the names of the operating companies. To avoid confusion these lines are not shown on the map of the proposed system.

The authors wish to express appreciation of suggestions made by Mr. H. A. Barre which led to the preparation of this paper.

DISCUSSION ON "CALIFORNIA 220,000-VOLT—1000-MILE—1,500,000-KW. TRANSMISSION BUS." (SORENSEN, COX, ARMSTRONG), LOS ANGELES, CAL., SEPTEMBER, 20, 1919.

Ralph Bennett: It is interesting to note that this paper can hardly be said to be in advance of actual construction since the lower half of the proposed line is already in operation in the Big Creek Line of the Southern California Edison, while the northern half of the transmission is under contemplation for immediate construction as the Pit River Line of the Pacific and Gas and Electric, and at the full contemplated voltage.

Our gain in reliability in the construction of power transmitting devises is no better illustrated than in the advance between the timid and temporary construction utilized in the latter 90's, and the substantial, permanent and well developed methods now at hand.

Yet it can hardly be said that there has been any considerable advance during this entire period in the abstract technical theory of the art. The change has been in the application of these abstract values to the concrete case of electrical transmission. This is well illustrated in the introduction as a matter of routine equipment of the use of synchronous condensers on these modern lines where the use of such apparatus was considered to be entirely experimental ten years ago.

It is probable that the change in the status of the business from the period of the latter 90's to the present date is greater than the change in its technical features. It is no longer possible to consider the electric lighting plant as a private enterprise. It is today a public utility extending over one or many states, and serving more territory than the average railroad system, and has come under state and Federal regulation more sharp and penetrating than the Government exercises over any other business.

The introduction during the past two years of inter-ties between the various physical properties of the Western power companies has long been foreshadowed. The paper proposes that these ties, now of a temporary and insufficient character, be rendered a permanent portion of the systems. Many companies will be fed by a common net work just as many railroad companies feed across their transfers, loads derived from many sources and intended for terminals as diversified as their origin. Under the ruling under which railroads have operated for a generation they are compelled as a matter of public policy to give equal care to all property entrusted to them regardless of its origin or its destination. They have become common carriers and far from rebelling from this condition they consider it to be an essential portion of their success.

The power business is rapidly developing all of the conditions which have surrounded railroad operation insofar as the interlinking of numerous independent companies is concerned.

It appears logical for conditions eventually so to shape themselves that the power company transmissions will become common carriers, not merely as the result of mutual agreements between existing monopolistic companies, but by action of law. As a result, any producer of power, however small, will be assured that his production will be received on the transmission net work, and that he will receive therefor a price fixed by a state regulating body on a basis of a fair return on his investment.

It is, I think, obvious to anyone acquainted with the present power situation that this would result in the construction of numerous small plants capable of introducing a fair amount of power as an incidental to the handling of water, natural gas, oil, or other power sources.

There are numerous cases within the knowledge of every engineer in this vicinity where considerable blocks of power could be produced on a schedule which would not permit of sale to a local net work, even if such sale were permitted by the railway commission, but where the production cost of the power would be so low that the power could be produced to great advantage if it could be successfully wholesaled to a net work capable of absorbing it regardless of its fluctuations.

Almost every irrigation system in the state possesses drops capable of producing a more or less considerable amount of power.

Numerous desirable combined irrigation and power projects are neglected because it has not been possible in the past to develop a market for the power, although the power in connection with irrigation could be produced at a very low figure.

On the north end of the Pacific coast there are sources of power as a by-product from wood working plants; there are coal mines lying undeveloped because they are not favorably located with reference to a rail haul market; in the oil producing industry vast quantities of oil and natural gas are wasted because they are unsuited to market demands or are in a location such that they cannot be successfully delivered to distant markets, yet they could be sources of large amounts of power which could be readily handled over a transmission bus.

It is unnecessary and perhaps aside from the purpose of the paper to go into detail on these items. The one other matter in the same connection however is of interest. Railroad electrification has been much discussed of recent years but has been to an extent held back by the very considerable problem involved in the extremely irregular use of power which will occur on most of the western roads.

Taken in connection with an ordinary local transmission this makes a load so undesirable as to render the power rate abnormally high.

But in connection with a centralized power system handling one or two million kilowatts these fluctuations would be regularly supplied by the excess capacity of the net work.

The problems of engineering, of finance and of political expediency involved in the changes now taking place in the relations of the power companies to each other, and to the public, are too great to even touch in this discussion.

P. D. Jennings: This paper is especially valuable at this time owing to the rapid advance of fuel prices and the necessity for the conservation of coal and oil for the essential industries that can not avail themselves of hydroelectric central station energy.

I believe, as this paper slightly implies, that this high-tension bus scheme could economically be carried out to include all of the great hydroelectric developments west of the Mississippi River. Of course it is not supposed that there would be an exchange of energy, say, between eastern Montana and southern California, but it is a fact that power plants on this bus line would have the great advantage of the diversity of load demanded, by substations, at the load centers along the line.

The two important considerations to be given, of course, are its operation and financing. It would appear to me that the operation of such a bus net work would require a unified control; and that the load dispatching work would have to be divided up into districts, or regions, which in turn would be responsible to an operating board of control composed of regional operating directors. This method of operation, of course, would require a unit scheme of financing. The probable formation of a holding company whose stock would be purchased and allocated by some equitable plan among all of the great generating systems interested.

Of course such a scheme would probably have many very serious disadvantages, from the individual standpoint of some of the companies involved, as well as some of the Public Service Commissions.

But these difficulties I do not believe would be insurmountable owing to the fact that both the public and the companies would be materially benefited by helping to reduce the rapidly increasing operating costs.

C. O. Poole: To my mind this proposed plan is one of the most important projects presented to the engineering profession from a conservation point of view. I have been, for years, a firm believer in this scheme and can see many advantages that will accrue from it, such as making possible comparatively small hydroelectric developments that will be in reach of the proposed bus, that would otherwise be too remote or without market for the output; or there may be streams suitable for power development that do not have storage facilities to equalize the flow throughout the year, in which event it would necessitate a steam plant in order to carry the load during the non-run-off periods. Under such conditions the investment to make this development might not be justified to supply an individual system, while with the proposed bus such a development might be advantageously made, simply utilizing the output of the stream while the run-off period is on. This same condition might apply also to irrigation systems where there are drops in the canals and water supply streams.

One of the principle advantages of connecting all generating and distributing systems to such a bus would be the improvement of the load factor conditions by diversity of both the generating capacities and the demands of the many diversified conditions of the different systems. For this same reason there would be less necessity for over-installation on water power generating systems, thereby very materially decreasing the spare unit investment and with its consequent less over head expense and reduction in cost for generation. From recent statistics the average yearly load factor of electric systems in the United States is only 30 per cent, and, while California's load factor is materially better than this, it is subject to much improvement.

As pointed out by the authors of the paper, and as theoretically set forth by Mr. Silver's paper in this volume, page 1037, the voltage proposed is not an impossible one to operate, but simply a matter of insulation and clearances. From a transmission point of view I might suggest, however, that the eleven units in the insulator string, as suggested by the authors, might be somewhat inadequate for the insulation of the new line unless insulators of a more reliable nature can be obtained than have been made use of in the past.

On this subject, the experiments cited in Mr. Silver's paper upon the dry arc-over and wet arc-over tests, are of unusual interest and it would seem that the line insulation should be based upon the curve of the wet arc-over, rather than of the dry arc-over conditions, inasmuch as the real test of the insulation is during storm and fog conditions, and, while from the curve mentioned the eleven insulators in the string might approach the flat portion of the dry arc-over curve, yet there is plenty of justification for adding more units in the string when the wet arc-over line on the curve is considered. The operation of such an important line as proposed should carry with it larger factors of safety than an individual system might economically call for, and, therefore, extra insulation in such a system would be, in my estimation, fully justified.

Special interest is attached to the probable conditions of corona loss upon this proposed line. I have been of the opinion for some time that it might be possible so to proportion sections of the transmission system of the higher voltages that the corona loss might be a means of dissipating energy in the event of over-voltages from any cause, and in the present instance it would seem that the line approaches this condition. In the event of an unusual high-voltage surge, energy would be dissipated to such an extent that it would tend to hold down the rise in voltage and, therefore, would be a benefit and protection to the system. I think this a feature that should be very carefully considered and experiments conducted beforehand to determine to what extent the corona loss could be utilized for the purpose mentioned.

Aside from the purely engineering conditions involved in such an undertaking there is another feature, to my mind quite as important as the strictly technical side of the situation, and that is the method of handling the different companies' input to the bus and the output from the bus. With a dozen or more companies taking from and feeding to such a system, many problems are involved that would have to be satisfactorily worked out, both as to the protection of individual systems from overload conditions, and also protection of the bus from service interruption. These features are engineering problems that can doubtless be worked out by a comprehensive system of relay switches. Probably a still more difficult situation is involved in the method of measurement of the current to and from the different companies. This last question also involves the ownership of the transmission bus, as to whether all the distributing companies would have ownership in the bus proportional to the capacities of their plants, or whether each should have ownership in the bus proportional to the kilowatt hours used by the different companies, and each company share its proportion of maintenance and overhead costs of the system, or whether an independent company should own the bus, this independent company being composed of the contributing companies and each of the contributing companies sharing in the ownership of the bus proportional to the sizes of their plants, or as to their proportional use of the bus. These are all much involved questions the solution of which, it seems, should rest jointly between the engineers, the commercial department and the financiers of the institutions involved. Personally I have not, so far, worked out any practical solution to this problem.

To my mind this proposed transmission bus should not be treated as some mythical thing to be considered in the far distant future, but as something that is now needed, and immediate consideration should be given to working out of all details involved in carrying the project to a successful issue.

J. D. Ross: There seems to be no reason why 220,000 volts should not be used commercially, providing the proper synchronous apparatus controls the voltage and providing the insulation has a good factor of safety. The cost of such long lines will, of course, be commercially feasible only where there are large quantities of power to justify the expense. It is probable that before many years this voltage will be considerably exceeded and will be considered moderate.

The city of Seattle is at present embarking on an enterprise on the Skagit River one hundred miles distant from the city. On a 50 per cent load factor, there will ultimately be developed at this point one-half million horse power. On account of this very large quantity of power, it is desired to limit the number of lines as far as possible by using high voltage and for this reason six lines are intended and the voltage will be 160,000. Had the distance been two or three times as great, 220,000 volts might reasonably have been used.

Three of the coast cities besides Seattle own their own electric power systems; Los Angeles, Pasadena and Tacoma.

Some years ago I spoke to the men in charge of these systems of the hope that some day there would be a high-voltage line paralleling the coast which would allow one city to help the other but at that time the voltages possible were not adequate. From Seattle to Los Angeles is about 1500 miles and it is a notable fact that the line at present under discussion is 1100 miles in length. Such a line along the coast would be a benefit to many of the smaller towns especially, and could be participated in by companies and municipalities alike. Of course, probably no city or combination of cities would attempt such a line but the best and largest water powers are rapidly being used up and when it comes later to the proper conservation of all such resources, no doubt the states affected will take a hand and interconnection between states would make such a line an actual fact. One of the great troubles which prevents interconnection of systems at the present time is the dissimilarity of voltage and phase relation and one of the greatest works that the Institute could do would be to bring about a better standardization of voltages.

Leslie F. Curtis: Dr. Magnusson, in the November 15, 1918 issue of the *Journal of Electricity,* considered some of the phases of a similar type of bus for the state of Washington. He selected the state of Washington because he happened to be familiar with conditions there.

The principal points brought out by Dr. Magnusson in his paper are advantages to be obtained by the Federal regulation of such a bus system. I am not prepared to advocate either Federal or private control. I will simply refer you to his paper.

J. B. Fisken: Professor Curtis has brought out the point that I wanted brought out. Dr. Magnusson advocates a Federally owned bus and I think there are numerous objections to such a scheme. There would be difficulty connected with the utilities working on a Federally owned bus.

H. A. Barre: On this general matter of government control, I think the big question, or the big trouble, with government ownership in that sort of thing is that you don't want the umpire to play on either of the teams. If the government would get out of the way and let us do the job, we can do it.

We are coming more and more to recognize the fact that neither the government, or companies, or financiers, or any other element, will have much to say about the development of this project. The development will be according to the natural economic laws which are as unalterable as the multiplication tables. Improper financing, improper engineering and improper relations between the companies and the public, and the public and the organizations of the companies, can gum up the whole game; they can delay it; they can interfere with it, but they can no more stop the building of it than the building of a dam across a river can stop the water for there comes a time when it does run over.

I do not think that this is a good time to sell the United States short. I think there is enough common horse sense in the United States and enough economic pressure for the carrying out of such schemes and we will get the proper answer in spite of all these things that are trying to interfere.

I object to the paper as a whole because I do not like such an arrangement. I do not think we should worry about a 1100 mile bus in California. I think when this thing does come it will come very quickly. It is going to be tied in with the Colorado power for a starter; then south through New Mexico to Albuquerque, Needles, Bakersfield, Mount Shasta, and wind up, as has been said, in Butte.

The great part of the work is done. There are already a great many interconnections. Those interconnections have been the means of a great economic saving in the past two years. Just in our little corner of the job, the San Joaquin Valley would have been absolutely shut down this year if it had not been possible for an arrangement to be made between the Edison, the San Joaquin, the Mt. Whitney, the San Diego and the Southern Sierras Companies. It is not very far from being shut down now as far as the shortage of power is concerned, but the job is still running and the amount of interference to service has been extremely small, that is true in spite of the fact that it was necessary to buy current from San Diego. One of the great stumbling blocks, of course, is the 50-cycle system in the middle of a big 60-cycle territory.

The French government has done a very intelligent thing. They have standardized the whole country at 50 cycles and standardized the voltages in multiples of the square root of 3, as high as anybody wants to go. I do not think anybody would want to go higher than the 110,000 or 120,000 volts at the present time.

That is a line along which we could follow to some advantage throughout the United States through the action of the Institute.

Such a line is not going to be difficult to operate. It will be broken up into regions, as has been suggested, in which a group of plants will supply a group of territories, or a group of loads, and means provided for an interconnection between those groups.

The control of the voltage is one of the most serious troubles and that is going to come through an extension of our work with synchronous condensers, without any question. The real instructive thing that has come out of this interchange is the fact that it has been possible for companies whose interests were to a very considerable extent antagonistic to get together on a broad enough basis to help out each other with their troubles and not try to take all the money the other fellow has when they do it.

L. M. Klauber: I do not know how it should be done, but I hope it will be done soon.

I think that one point that Mr. Barre brought out is of considerable interest; this is that all of these things will be easier to do after they are done. They work themselves out beautifully. A lot of the problems that have been causing us sleepless nights (I refer to problems not of engineering but of operation and management) have really eliminated themselves. We sometimes wake up in the morning and find that the solutions which have bothered us for six months have already been accomplished and that the difficulties which worried us have failed to materialize when the time came.

You probably noticed a brief editorial in a recent copy of the *Journal of Electricity*, wherein it was stated that when the Pacific Fleet came into San Diego Bay, the Crane Valley reservoir of the San Joaquin Light and Power Company, distant many hundreds of miles and three companies from San Diego, had to be drawn on for an extra amount of energy. This, of course, is an interesting proposition. It would be somewhat more interesting, if true, which was not the case. As a matter of fact the shortage on that particular day was due to a defective condenser.

I think that the transmission bus, when the time comes, will work itself out without the difficulties in financing, in operation and in government supervision, which now appear almost insurmountable.

J. A. Lighthipe: I think Mr. Barre is perfectly right when he made the statement that while we are struggling and talking about this proposed bus, we will have it. Nothing is improbable and these great projects simply spring up when the need is there.

The great problem of this business is not only the diversity of the distribution, it is the great diversity of the supply. Our water sheds in California are very erratic and diversified. That problem within itself is a great one.

We have Railroad Commissioners who do not interfere with us. They pat us on the back and tell us to go ahead. As long as the State of California has a Public Service Commission, such as the Railroad Commissioners, with a modern man at the head of it, this matter of public control is not going to bother us.

It is a beautiful thing to talk Socialism and it is a beautiful thing to talk public ownership, but it does not get us anywhere. A man with the nerve will get hold of these projects and bring them to a proper solution. The State of California has reaped the benefit of the pioneers of the power situation and will continue to do so.

The question of voltage is an interesting one. When we had 10,000 volts we were afraid of it; we never dreamed of such a thing in our lives. When Southern California sprung to 33,000 volts even the manufacturers of apparatus shook their heads with uncertainty. I remember a man, in the early days who stated that 50,000 volts would be the ultimate we could hope for. That statement was made in the days when we knew nothing about all these modern troubles and the talk about a 50,000 voltage was thought impossible. However, we kept creeping up until we reached 60,000 volts and then 150,000 volts. We have also learned that the higher the voltage the less trouble we have. That is probably due to the fact that the engineers on the job have worked more thoroughly; that is, we know what we are running into and we build to meet that condition.

The future of the state is so great, where the price of oil used is ever increasing; where every bit of power in this state should be developed; where this power should be used and where we should start a campaign of conservation on what we have in the state.

P. M. Downing: It is very interesting to look at a map and see a 1500-mile bus extending from somewhere in British Columbia or the Northern part of Washington down to the Southern part of California or into Arizona, and from an engineering viewpoint we are able to convince ourselves that the problem is not one impossible of solution. In my opinion the real problem is not one of engineering but rather one of economics. There is no doubt but what in time the generation of power by the use of oil must be superseded almost entirely by water, and yet, at the same time, I do not know of any one particular state or district on this Coast that is going to have a sufficient surplus of hydro power to justify a high-voltage bus such as for transmitting energy from one state to another or from the system of one operating company to the system of another. There is no doubt in my mind but what in a very short time we will see lines operating at voltages as high or even higher than 220,000, but there is an economic limit to the distance that power can be transmitted. There is potential water power all along this coast from Alaska to Mexico that can be developed to meet the local demands. I look for a more general standardization of voltages and frequencies on the systems of the various operating companies and a more general interconnection of the various systems. If these interconnections can be looked upon as forming a bus, I feel that in time we may reasonably expect it to become a reality, but, obviously, interconnections of greater capacity that are necessary to carry the limited amount of energy that will be interchanged, cannot be justified.

When I say that the engineering problems can be more readily overcome than the commercial or economic ones I have in mind, particularly, an arrangement that was made a year or two ago between three of the companies in the northern part of the State of California. Those systems were tied together as a matter of economy and for the utilization of surplus power available.

When that tie-in was proposed it took the engineers but a short time to work out the engineering problems involved. It happened, however, that I also had something to do with drafting the final contract. It took us about three months to get the commercial details worked out. If there had been a larger number of companies involved, the problem would have been a correspondingly more difficult one. The physical or engineering details are simple, and can be taken care of very readily. So I say the whole problem is an economic one. Can any company, or any number of companies, or the State or Federal Government, afford to generate power up in the extreme northern part of this State and transmit it down to San Diego, when there is power nearer San Diego than that in the north? I do not look for a bus of great capacity to be built in the immediate future, except such as might result from the normal interconnection of lines of companies operating in contiguous territory. Negotiations are now under way looking for a connection between the lines of the Pacific Gas & Elec. Co. and those of the San Joaquin Light & Power Corporation. This connection will be made within a comparatively short time and when completed will give a connection from Oregon to San Diego. This connection is of limited capacity but is serving every purpose and in view of the amount of power that is available, a line of greater capacity cannot be justified. Interconnections between the various systems are very desirable and will continue to be made at whatever voltages the systems may operate, but until there is an apparent necessity for a bus I think we may reasonably conclude that the necessary capital to construct one will not be forthcoming.

J. B. Fisken: Mr. Downing has raised a question as to the advisability of this bus line. Personally, I think he is right and that this will solve itself in the interconnection of different systems without any great transfer of power over long distances. I do not ever expect to see the power from Spokane utilized in San Diego.

I see no reason, however, why Spokane power should not relieve some other power that could be transmitted a shorter distance.

This problem, I think, is largely a western one, but perhaps Mr. Stevens can tell us how they do these things in Pennsylvania.

J. F. Stevens. I would have given a great deal if, during the war, such a plan as is proposed in this paper had been in operation in the East, or even if there had been such limited inter-connections as you now have.

It happened that I was connected with one of the Government agencies which had to do with the power situation in Southeastern Pennsylvania. We were confronted with the fact that there was a distinct shortage of power in our district, not only a shortage of coal but also a shortage of generating capacity in our public service power plants. This meant that every pound of coal burned had to be burned at maximum efficiency and every generating plant operated at maximum capacity in order to secure the power necessary for the operation of our war industries.

The natural solution seemed to be a combination of the resources of the power companies operating in the district by tie-in connections which would render available their full generating capacity which then could be distributed to the various industries irrespective of their location. With this in view a conference was called and I found the power companies very willing to discuss the problem but without available funds with which to practically effect a tie-in. They were operating at from 25 to 60 cycles transmitting voltages from two thousand to sixty thousand so that the cost of installing frequency changers and transformers was considerable. The Government was prepared to spend unlimited millions in other directions but, while recognizing that power was essential to production, refused to appropriate any funds for the purpose of tying together the power plants of this district. We found ourselves in the usual position of a war-time bureau with authority to commandeer a tie-in but no authority to expend money for it or to compel the companies to spend money.

As a solution we had introduced into Congress a bill appropriating two hundred millions of dollars for the purpose of constructing power stations located at the mine mouth and erecting transmission lines to serve the district from Washington to New York. This bill failed of passage and, in view of the fact that it would probably have resulted in federal ownership and operation, I am not particularly sorry, for few of us in the East look with favor upon government ownership. The net result, however, has been to stimulate interest in power generation at the mine mouth in stations equipped with large units and transmitting over a very considerable radius. You are fortunate in having available water powers which are almost totally absent in Eastern Pennsylvania but we have as partial compensation large deposits of fuel coal of excellent quality.

Some experiments have been made and the results so far achieved have been exceedingly satisfactory, particularly in localities where there were a considerable number of small public service or municipal plants, and it bids fair to be a solution of the old municipal plant problem. It happens that back in the early days of electric lighting there was quite a mania for municipal ownership of lighting plants and almost all of them have fallen into sorry condition. In order to construct the plants the town would be bonded and no provision made for a sinking fund. They are, therefore, now in the position where they have an obsolete plant with a bond issue against it and no funds for the redemption of the bonds or for the reconstruction of the plant. I have in mind one such plant in Southern Ohio where the municipality was generating at a cost of from nine to twelve cents and selling at four and there are many more like it. They had no money with which to modernize their plant and even if they had the load was not sufficient to bring their generating cost down to a point where they could sell at a profit. The solution was found by establishing a generating plant at a mine not far distant and furnishing power to this town as one of its customers at a price which enabled them to sell to their citizens at a profit by transforming their generating station into a substation.

I firmly believe the time will come when all power in my district will be generated at the mine mouth, the various plants being tied in together on a common bus and distributed to various substations. You on the Pacific Coast have the advantage of water power and I think your plan most admirable. Even the discussion has been typical for when I came in the room the length of the transmission line was given at 570 miles and has now grown to 1500 miles but even the latter figure does not seem unreasonable in view of the existing situation. It is not, to my mind, the question of whether you have local power enough to meet the demands of each locality or whether you could expand your plants so as to secure it. It is the ability to interchange power, supply deficiencies and take care of break downs which is so very valuable. There have been many cases in the East where one large generator would go out in a public service plant which meant a shortage of power and light in that district which shortage could have been cared for had it been possible to tie-in with other power companies operating in the immediate neighborhood.

It does not seem to me that the plan here proposed presents any serious difficulties. The project naturally divides itself into generation, transmission and distribution. The various generating companies sell their power to the transmission companies which in turn would sell to the distributing companies in proportion to their demand. While there are some operative problems yet to be solved the principal problem is one of finance.

Relative to the operating end, I will state that in the East we have quite generally adopted a system of parallel transmission lines. As a rule we do not run two or more circuits on one pole line but mount each circuit on separately located pole lines half a mile or more apart. This practise has tended to save us from lightning troubles and break downs in the transmission circuits.

C. W. Koiner: I have been thinking of this paper along the line of economics. It appeals to me as practically suggesting the interconnections which saved us a great deal during the period of the war. If interconnection and tieing in, whether by as long a bus as this or a shorter one, is good in times of war it certainly ought to be good in time of peace.

The diversity factor which has been touched on by Mr. Lighthipe is the keystone of the light and power business. Without diversity we all would be in some other line of business because there would be no money in the power business under present conditions and circumstances of operation. There would be the gathering up of the crumbs, as it were, of the tieing in the plants that have water during some seasons of the year and none at others, enabling storage to be made, and all the other ways that would tend to mutually help out in times of stress.

I do not think of this paper as applying to the Pacific Coast particularly, but I am thinking of what Mr. Stevens touched on in the East during the war. The fact that the great coal mines lie close to the seaboard, would have made it a wonderful thing to have had the advantage of tying-in during the war. Why haul the coal and cinders and ashes to the seaboard and then cart them out of the city after making the buildings black, creating a lot of dirt producing and inefficient steam plants?

I think this principle was recognized ten or twelve years ago, or longer, but there are a great many things that enter into the problem, one of which has been touched on here and on which, I think, the Chairman invited discussion—government ownership and regulation.

It seems to me that it cannot be accomplished without regulation. Mr. Barre says that they try to rob one another and that they must have an umpire to prevent that kind of thing. The fellow who is able to take advantage, or figure the closest, will get the better of the other, figuratively speaking.

Now, to deny that the government has not the ability to even generate this power and deliver it to the distributor, or regulate it, is to deny that we are capable of efficiently living under democracy. Our government is supposed to be a democracy; therefore, if you cannot solve a problem by and for the people of this character, then we need a boss; we need somebody who will crack the whip over us and make us perform efficient service.

I am not one that believes that we are not capable of doing these things; I know we are. Some of the obstacles are the opposition of those who are entrenched. We may have stock in companies that have the water power cites, and we want more; we can make more money than if we let the government own it and run it for the people. Consequently, we as engineers are working for that side of the house and we naturally are opposed to government ownership and even regulation. But, some of the wiser heads, such as Mr. Phillip Cabot who wrote an excellent paper recently published in the *Electrical World*, recognizes that government regulation is here to stay and that even government ownership is coming on certain things. The water power belongs to all of the people; so does the coal. Somebody happened to see it first and, therefore, the coal is in the hands of private interests, yet the economic life of the country depends upon coal. Now, all monopolies should be controlled, or rather owned by the government.

I am not a Socialist, however; I am not making apologies for I believe in what I say. I believe that the water power of this country must be conserved or passed into the hands of private interests the same as the coal mines, and without regulation and proper control, the people of the state or of the various states, might not get the benefit. We must have regulation for the purpose of interchanging power between the states. It cannot be done without it.

When it came to winning the war we had to work as a government, all pulling together for the same thing. Now, in these problems we have to do the same thing and we might just as well face the problem in that way.

J. F. Stevens: The last speaker has touched upon the question of government ownership and I want to give you one example of the efficiency of government ownership in this line—something with which the Institute was very closely associated.

Just about the time of our entrance into the war, the Institute, seeing the seriousness of the power situation and recognizing that the defense of New York from attack by sea rested in Governors Island, called General Leonard Wood, then in command of the Island, into conference on the subject. We called attention to the fact that the Island was dependent upon the operation of its own power plant, government owned and operated, without which it would be impossible to use the search lights, ammunition hoists or even aim or fire the big guns, and that the failure of the plant, either through the act of an enemy or by accident, would leave New York defenseless from attack.

General Wood acknowledged that our statement of the situation was correct and asked for our solution. We told him we had a large amount of power in and around New York which we were prepared to tie together and deliver to him on Governors Island through submarine cables for use as an auxiliary to or a substitute for the Island plant. His reply was that the government had no appropriation with which to pay for such service. We then offered to raise the money necessary to pay for the tie lines and to buy and lay the cable. Then, to our surprise, he told us there was a regulation which prevented the landing of a cable for any purpose whatsoever on such a government reservation as Governors Island and that it would require an act of Congress to enable the Army to take advantage of our generous offer. Such an act was introduced into Congress but never has been passed. From this you can see the sort of efficiency we may expect from government ownership of utilities.

J. A. Lighthipe: Mr. Koiner said he was not a Socialist. I want to tell him that we all are. I want to say that when we want anything done in a hurry we always have to do it ourselves. I want to tell Mr. Koiner that the money he has accumulated during his lifetime does not belong to him—it belongs to Uncle Sam, and when he dies it goes to the government. Of course, the government does not want to take it all; it allows him some to will to his wife and children and the part the government gets is called inheritance tax.

I suppose Mr Koiner thinks he owns the money his employers pay to him. He does not do anything of the sort. Of course he uses some of it, but the government takes the rest and it is called Income Tax.

Now, this would be a wonderful thing to develop these water resources. It ought to be done as an economic measure, but Uncle Sam has not got any money and how are we going to solve the problem? The government will do this: We will let the individual people invest their money in a Public Utility Corporation, but we are not going to let them run it and bamboozle the country. What we are going to do is to put our own directors in there and tell them how their money is going to be spent; tell them just how much money they can borrow and criticize their method of construction. We are going to tell them how great dividends they are to pay. We call that the Railroad Commission.

That is just what we are running into. If we are going to have any public enterprise in this country, we are not going to have Uncle Sam start it because he is a little too slow. We are going to have the individual enterprising pioneers of this country develop all this power and we are going to have the Railroad Commissioners regulate our rates, etc. This will be done because, although Uncle Sam has not the money to do it, and is never ready to give it to us, he will tell us to put our money in and he will see that it is handled properly and that we get a good interest on the investment. But there will be no watered stock and no high financing. Consequently, every move we make, whether it be the purchase of something; or the installation of a new steam plant; or the installation of various water powers, we make our plans and submit them to the Railroad Commission. They figure out whether we really need this plant, whether the cost would be excessive, and then tell us to go ahead. You then have the endorsement of the Railroad Commission.

Mr. Koiner stated that this thing can not go on without some control. I say we are under control. We cannot make a move in this state without the sanction of our Railroad Commissioners and we are fortunate to have a very liberal set of men at the head of that Commission. We welcome this regulation because we are infinitely better off than some of the other cities that own their plants, because we keep our books in a certain way, as they tell us to; we have a sinking fund, which is lacking in some of our city plants and we are allowed a depreciation which is properly agreed upon. In other words the whole thing is run by the Public Utilities, only we are running it under the direction of the state of California.

Lester S. Ready: I wish to say that I am optimistic regarding the installation of a transmission bus running throughout the State of California. From what we have seen during the last three or four years of the spirit of cooperation by the utilities during the period of the war we cannot help but realize that the problem is not an impossible one.

I believe that if it had been said five or six years ago that the various utilities in Southern California would have stood together during the period of short water supply and not taken advantage of each other the remark would have been considered almost ridiculous. Yet, during the past year the supply of electric power in the southern and central part of California has been divided between the companies, the company with additional supply rendering service to its competitor at reasonable rates. Steam-electric power produced in Los Angeles and San Diego has been used to make possible the supplying of adequate service in the San Joaquin Valley, where a material shortage occurred.

The big supply of hydroelectric power of the state is in the northern section. There is not a great deal of hydroelectric power developed or to be developed, in the south. The Southern California Edison Company has built its lines from Big Creek and there is still a great deal of undeveloped power on that stream which ultimately will be transmitted south of Tehachapi. It is doubtful whether the power supply of the development when fully completed will more than half supply the demands of Southern California, and power from the northern part of the state must be transmitted southward.

Glancing at a map of the state you will see that all of the transmission lines lead southward, and at present the general flow of power is in that direction. There may never be a great deal of power produced on the Pit or Feather Rivers delivered to Los Angeles, but these rivers will relieve the demand upon the plants south of them, so that these in turn may be relieved to supply the demands further south.

From a physical standpoint there are practically only two transmission systems in the state at the present time. From Merced north to the Oregon line there is a great network at present completely interconnected. All companies south of Merced form another great system fully interconnected, and it is not only possible but probable that within six months or a year there will be an interconnection between these two main systems.

The war has done a great deal of good toward the development of interconnections between the utilities in this state and its affect will be a lasting benefit to the state as a result. The district in the south is requiring the full capacity of all the power plants and were it not for interconnection there would be a great shortage of power in the San Joaquin Valley at the present time.

The Railroad Commission is ready to do its part in fostering the interconnections which should be made. It made special efforts during the war to assist in the full conservative use of the power supply of the state and I wish to state that we are very pleased with the way things have been carried out, and the electrical engineers have much to their credit. I am not fully advised of the basis by which Mr. Barre determined the rates which were charged between the companies during the emergency but am certain there has been no profiteering between the companies during this period.

George A. Damon: One great thing that we are doing right here in connection with this proposed high-tension bus line is to establish a "sense of direction." We may not, just at present, be certain of all of the details—or how the enterprise is to be accomplished but I am sure we all feel that we are on the way. The situation is something like the starting of a foot ball game: we all know where the goal is but we are not at all sure of what each play will be to take us across the goal line. We may be quite certain, however, that if we all start in the right direction and stay together by constantly co-operating, eventually, we will accomplish this very desirable advance in the art.

I think it is quite immaterial to the project, at this time, to consider whether the cost is to be financed "individually" or "collectively"—that is by private capital or by public funds. We all love the democracy which we retained at the cost of the great war and recognize that our next problem is to strike an equitable balance between individual interests and the common welfare. My own sense of direction seems to indicate that the economic pressure of the need of this great interconnecting bus will evolve its own system or method of financing and that, as electrical engineers, we need not stumble or hesitate over this difficulty.

From our own technical standpoint the great big important problem which we have not yet discussed is the question of frequency. As we all know we have in use in this part of the country both 50 cycles and 60 cycles. If I am properly informed about 25 per cent of our load is on a 50-cycle system. Under these circumstances we have yet to determine the cost and practicability of combining these two frequencies into one system. We are constantly and rapidly increasing the load on each of the two systems of distribution but here we are seriously considering the tying together of all sources of generation or supply by means of one great interconnecting tie line. Under these circumstances what do we propose to do eventually with these two frequencies? In my opinion this is the real electrical problem to which we should just at this time, address ourselves.

L. M. Klauber: I think that the question of frequency is somewhat like some of these economic problems—it will solve itself over night. The Edison Company has always claimed that 50 cycles is the proper frequency and that operation would be impossible at any other. However, last week when the engineering staff was not watching, the system speeded up to something like 59½ cycles and operated that way for about two minutes; they could as easily do it for two years.

L. J. Corbett: As has been stated, the electrical features involved in the line projected have not been discussed very much. It occurred to me after looking over this paper and listening to the remarks thus far, that some of these points have not been taken up because they are not of extreme importance from an electrical viewpoint. When you have a system as long as the one contemplated, with plants connected in at short distances apart, the actual effect on the system, at San Diego, for instance, due to connecting in the plant at Spokane, would not be of great importance, because the load at San Diego would be taken care of by the plants in the closer vicinity. Only in certain cases where for some reason an entire district would be cut out, would we have even the problem of a long distance transmission line arising. It may be recalled that in the case of a long line there are differences in wave form which result from the transmission line characteristics, but it is my opinion that these would be almost eliminated in such a system as outlined here.

As has been stated by one of the speakers, a 220,000-volt line is not necessary, as an interconnection of the ordinary existing systems, whether 30,000, 50,000, 60,000, 110,000 or 150,000 volts, can be made. The lines can be interconnected just as they are by using proper transformer substations. As for the different frequencies encountered, that feature would present a minor difficulty; it would be an economic question solely, as it would call merely for the additional cost of a frequency changer when connection is made to a plant of a different frequency. It seems to me that everything required can be done with a lower voltage line and with equipment already in use or available.

J. H. Anderton: All previous discussions on this paper have given practically no weight to the engineering problems involved in the design and operation of the proposed line. In fact, it has been stated here that the engineering problems are comparatively simple. This may be quite correct if the comparison be made with the financial side of the problem. I do not believe, however, that we should assume the engineering features as a negligible factor. For instance, I note from the figures given on page 1240 of the paper that the distance between Pit River and Los Angeles is 570 miles; to San Diego it would be approximately 700 miles. These distances are, of course, more or less approximate and while they approach the quarter-wave length of 60-cycle propagation, there will be no danger from this standpoint alone since a practical line has resistance and other constants which prevent the theoretical rise due to the quarter-wave length distance. However, with lines of any length and given constants, a point of highest receiver voltage and maximum charging kv-a. can be found. The converse is also true that with a given length certain constants will give the highest receiver voltage and maximum charging kv-a. With a line of the length under consideration, the use of normal line constants might reasonably give a receiver voltage of from 250 to 400 per cent of the normal generator voltage, assuming that the line were charged from one end. This latter assumption is, of course, impossible due to the kv-a. capacity which will be required to charge the line but indicates in a general way the necessity for a careful determination of all the constants. The complexity of the problem is very apparent from the fact that the line may be operated as a whole or in part and could be charged from various sources.

H. H. Cox: The idea in preparing this paper was that it is now time for some large development in California. California can use 100,000 or 200,000-kw. water power now and relieve the steam plants and shut off the use of fuel. You all know the price of fuel. Fuel means something more to us. In a pound of oil there is a whole lot of other things more valuable than the thermal unit. Therefore, the use of fuel is going to be turned in another direction to make these chemical products, giving us the use of the by-products.

Our confidence in the operation possibilities of the high-voltage line is absolute. We don't think there will be any difficulty at all. In answer to Mr. Anderton, regarding the distance of 750 miles, more or less, this system would never be operated as a transmission from Pit River to Los Angeles. You would have to get the individual sections together. That is, one line from Pit River to San Francisco and another from Big Creek to Los Angeles; then the two would be gotten together and power interchanged. It would be a physical impossibility to build up a line of this distance with generators because the quarter-wave length would act as a short circuit on the line.

In regard to the operation of the line, we state that complete parallel operation of all lines must be adhered to in the proposed system. Satisfactory protective relay systems for dropping defective sections with little disturbances have been developed for present parallel transmission lines and there appear to be no obstacles to extending these to the higher voltages. Such protective relay systems have been in use on 60-kv. systems and are operating satisfactorily.

This transmission bus, as I have said, will probably never transmit power from north to south, but it will be a means of caring for emergencies and transmitting surplus energy to take care of the diversity of the different loads.

The present interconnections have a very limited capacity, as you all know. One company may now have 10,000 kw. to spare and puts in an interconnection of that size. Tomorrow an emergency arises and the other company needs 20,000 kw. The interconnection would not carry it. In the beginning of our paper we assumed the interconnection of all the California power companies on an equitable cost basis. It is now time for a large development of power to take place in California.

G. E. Armstrong: I just overheard, from Mr. Downing, the remark that we will have a job to justify this line. It doesn't look that way to us. In the first place, Mr. Downing said that California had lots of power, I suppose ten years ago that the power we have now looked like quite a bit. When I first came with the Southern California Edison Company we had a peak of 30,000 or 40,000 kw. and we are now running over 175,000 kw. The increase is going on a percentage basis. When on that basis, and the percentage increasing every year, we are going to pick up load pretty fast.

Mr. Downing thinks he won't live to see this line an accomplished fact. I would like to call his attention to one point. For instance, the Southern California Edison Company, if this line isn't put in, is going to need an additional 150,000-volt line to Big Creek very shortly. The two lines we have now are sufficient for about 60,000 kv-a. each. The two Big Creek plants now have a capacity of 60,000 kv-a. The installation of another plant there will bring it up to 100,000 next year and we will need more for the next year. If the voltage is raised to 220,000 shortly, the capacity of each line would be about 125,000. This was the idea that we had in mind as a need of bringing this proposed line in operation.

The San Joaquin Light and Power Co. now needs a transmission line running north and south and having a voltage of at least 110,000; that is what they are figuring on. You can easily see that it would be a waste of money for them to build a line of that capacity when the Big Creek line at 220,000 volts could take care of both the Edison Company and the San Joaquin Light and Power Company.

There is one other point. The longer this proposition is put off, the harder it will be to accomplish it. If it is necessary for the Southern California Edison Company to build another 150,000-volt line to Big Creek, it would not be very favorable to changing to 60 cycles. This same thing would be true of any of the companies in the northern part of the state who find it necessary to extend their lines in the near future. But, if this bus line is considered now and worked out in a reasonable way, I don't see why the next lines could not be built having in view the interconnection of the systems, so they could be operated at 220,000 volts when the time comes.