ST. PAUL TO ELECTRIFY OVER CASCADE MOUNTAINS*

By K. R. Hare

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The electrical operation of the C., M. & St. P. Ry. over the Rocky Mountain range is proving so thoroughly successful that the directors have authorized the electrification of the lines over the Cascade Mountains. The extent of the proposed work is described in the following article.—Editor.

On Thursday, January 25, the board of directors of the Chicago, Milwaukee & St. Paul voted to extend its electrified zone from Othello, Wash., west to the Pacific Coast. The new electrification involves about 250 miles of main line and will cost approximately $6,250,000, exclusive of locomotives, but including bonding, catenary, transmission lines and substations. Contracts for the material and equipment required will be placed in the near future and work will be started as soon as possible. It is expected that the extension will be in operation some time during the year 1918.

characterized by easy grades and few curves. West of Othello, however, are the grades encountered in the Columbia river valley and the extremely mountainous district over the Cascade mountains between the Columbia river and Seattle, including the 12,000 ft. tunnel at Snoqualmie Pass. Fig. 2 is a profile of the St. Paul line between Othello and Seattle; reference to it will show that there is 37 miles of 0.4 per cent ruling grade between Othello and Beverly on the Columbia river and about 20 miles of 2 per cent ruling grade from there west to a point several miles east of the cascade tunnel between Keechelus

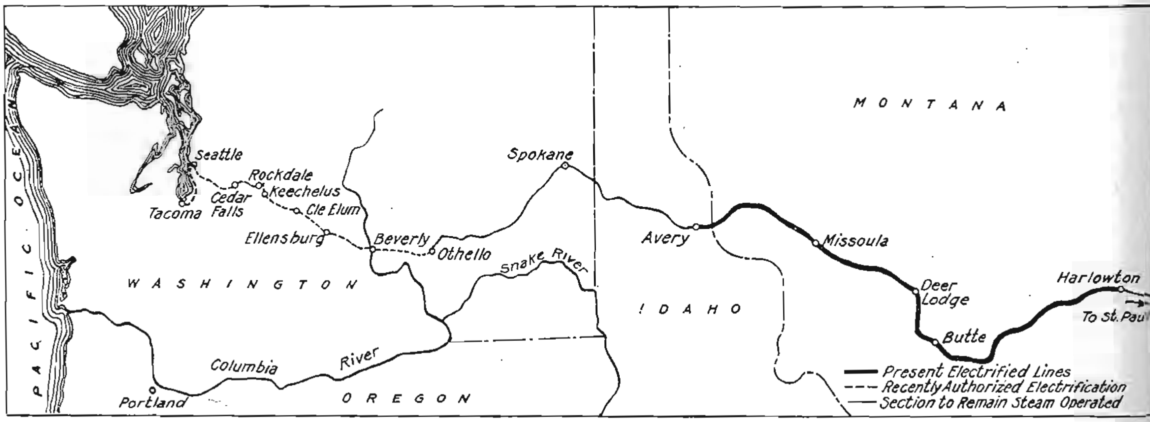

Fig. 1. Map showing Section of C., M. & St. P. now Electrified and to be Electrified

By referring to Fig. 1 it will be seen that the eastern terminus of the new electric zone will be about 225 miles west of Avery, Idaho, the western terminus of the section of line now under electric operation. This means that the district or section of line between Avery and Othello will continue to be steam operated. When the present plans are completed the St. Paul will be electrically operated from Harlowton, Mont., to Avery, Idaho; and from Othello, Wash., to Seattle and Tacoma, Wash., a total of approximately 690 miles, which is a distance practically equal to that from New York to Cleveland, Ohio.

It is not considered economical at this time to electrify the section between Avery and Othello, as between these two points the St. Paul traverses rather level country

and Rockdale. West of the tunnel the line descends for 19 miles on a 1.7 per cent ruling grade to Cedar Falls, and between Cedar Falls and Seattle, a distance of 40 miles, the ruling grade is 0.8 per cent. Due to the mountainous country traversed by this section of the St. Paul, the curvature is necessarily heavy and in this respect closely resembles the character of the line between Harlowton, Mont., and Avery, Idaho.

The traffic consists of three passenger trains and an average of from four to six tonnage freight trains each way daily. The direction of heavy tonnage is eastbound. One Mallet locomotive now brings 2,100 tons eastbound to Cedar Falls, where a Mallet helper is put on for the 1.7 per cent grade to the tunnel at Rockdale. Under the proposed electrical

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operation, one electric locomotive will bring about 3,000 tons to Cedar Falls, and an electric pusher will be used for the steep grade from there to the tunnel. Besides the increase in tonnage, the speed on the heavy grade section, now very low under steam operation, should be about doubled.

System to Be Used

The same system of electrification will be used on the new extension as has been used and found so successful on the original section electrified. The electric locomotives which will be purchased to operate over the new electrified zone will be identical with those in service on the Montana electrification. The same double-trolley, wooden pole, catenary construction and the same type of transmission line and system of feeders will be used, as the several months' trial of the present installation has indicated that no changes in these details are necessary or advisable. Briefly, the system of operation will be 3,000 volts direct current at the trolley, energy at this potential being furnished from substations containing motor-generator sets and transformers supplied from transmission lines of various hydro-electric companies, supplemented by a 100,000-volt line paralleling the track and owned by the railroad company.

The electric locomotives will each be constructed of two units permanently coupled together, the halves being duplicates, but each half capable of independent operation. The locomotives weigh 282 tons, have a running tractive force of 85,000 lb. and a starting tractive force of 126,000 lb. The passenger locomotives have a gear ratio permitting the operation of 800-ton trains at a speed of approximately 60 miles an hour on tangent level track. The average passenger train on the St. Paul weighs from 650 to 700 tons and is hauled over the two per cent grades of the present electrified divisions without a helper. The freight locomotives are designed to haul 2,500 tons up a one per cent grade at 16 miles an hour, and on the Rocky Mountain electrification two of them have been used successfully to haul 3,500 tons on a two per cent grade. In many cases it was found necessary to increase the length of the passing siding so that the maximum hauling capacity of the locomotive could be utilized.

The decision to use, on the extension, the same system and the same type of equipment which is now being used speaks well for the success of 3,000-volt direct-current operation for heavy main line service. C. A. Goodnow, assistant to the president, in charge of electrification on the St. Paul, states that he is particularly impressed with the satisfactory manner in which the locomotives are running, and with the ease and speed with which they handle the heavy trains over the grades and curves encountered on the mountain divisions. It is a literal fact that the present electrification has eliminated the Rocky mountains as far as railroad operation is concerned on the St. Paul.

On the Rocky mountain electrified division the running time for both freight and passenger trains has been reduced by about 30 per cent, and operation under this schedule has proven most reliable; in fact, the electric locomotives are now counted on to make up the time lost on adjacent steam operated divisions. The increased reliability obtained by the use of the electric locomotive is one

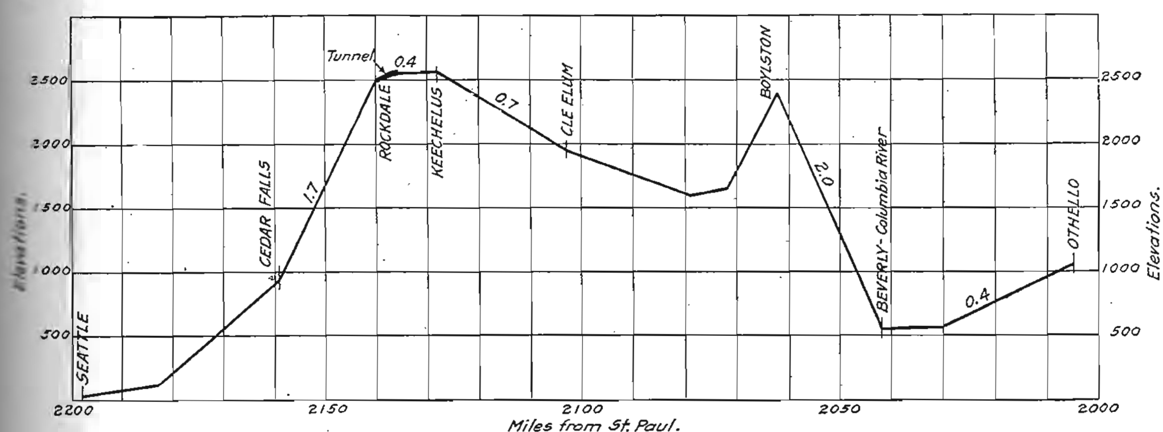

Fig. 2. Profile of Section of Railway to be Electrified

of the chief advantages of electric operation. The electric locomotives keep going with a full tonnage train under all conditions of weather and over all kinds of road.

When trains are hauled by electric locomotives it is found that their movement is so uniform and that failures of the electrical equipment are so rare that one set of train despatchers can easily handle trains on the section now under electrical operation where two sets were required under steam operation. Under electrical operation the time between Three Forks and Deer Lodge has been reduced from 12 to 8 hours for heavy freight trains and in addition the tonnage has been increased on the maximum grades from 1,700 to about 3,000 tons. This tonnage is now handled at the speed of about 16 miles an hour on the heaviest grades, whereas the best that the steam engine could do with the lighter trains was about 8 miles an hour. The electric locomotives, which will be used on the new section, often cover 250 miles a day on the Rocky mountain division and are standing up under this hard service extremely well. Mr. Goodnow, when talking about this feature of electrical operation, said that present indications tended to show that the maintenance cost of the electric locomotive will be remarkably low.

The locomotives used between Othello and Seattle will naturally be equipped for regenerative braking, as this feature of the locomotives now in use has given great satisfaction. Mr. Goodnow states that regeneration effects a saving of approximately 14 per cent based on power used at the locomotive.

Power Supply

The general scheme for supplying electrical energy to the trains on the new electrification will be the same substantially as that adopted for the Montana installation. The power will be supplied by hydro-electric developments in Spokane, in the Cascade mountains and on the Pacific coast; all power will be purchased from private corporations. The contracts for furnishing such power will provide for about 40,000 kilowatts and each will contain an option covering whatever additional power may be necessay to take care of increased business. The cost of electric current will be approximately ½ cent per kilowatt hour and there will probably be provisions similar to those in the contract made with the Montana Power Company, which provides that the power-factor be limited to a variation of 20 per cent from unity and that the monthly load-factor will be equivalent to 60 per cent, when based on the contract load.

One of the greatest economies to be effected by the proposed electrification will be the saving in the cost of energy required to haul the trains. The railroad company's oil contracts have expired, and any new contract which it makes for oil will be based on a considerably higher price for this fuel. On the other hand, the contract which the railroad company entered into with the Montana Power Company for furnishing current for the Rocky mountain electrification runs for 99 years, during which time no changes in the cost of current can be made.

In connection with the advantages to be obtained by electrical operation it is interest-

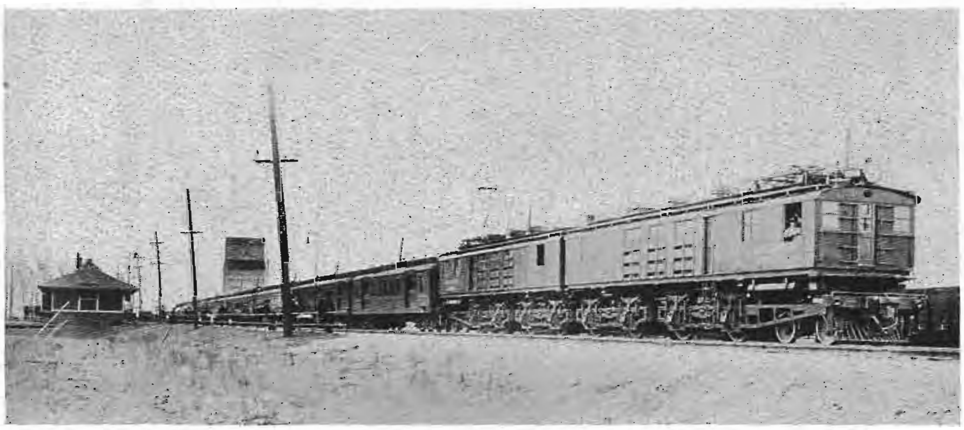

Fig. 3. Electric Locomotive Coupled to Passenger Train on the C., M. & St. P.

ing to note that neither of the electrification projects of the St. Paul have been made necessary because of nuisance caused by locomotive smoke, congestion at terminals or at tunnels, but both were brought about because of the economy that can be effected by the substitution of electric for steam power. This economy will be particularly felt in both of the electrification districts because of the presence in each of cheap hydro-electric power, which fact has been an important factor in the decisions to electrify.

History of the St. Paul Electrification

Although the subject of electrification had been under consideration for some time it was not until November, 1914, that a contract was actually placed for equipment and material necessary to electrify the 113 mile division between Three Forks and Deer Lodge, Mont. This was simply the first step in a scheme which involved the extension of the electrified zone to cover 440 route miles between Harlowton, Mont., and Avery, Idaho, on the west; the whole foreshadowing the ultimate electrification of the main line to the Pacific coast. In view of the magnitude of the project, the progress which has been made is remarkable. By November, 1915, overhead construction had been completed for a distance of 200 miles and the 100,000-volt transmission line, which was erected by the railroad on its own right of way, had been completed for an equal distance and the lines from the Montana Power Company were ready for service. At that time the trackage actually ready for train operation included yards and sidings at Three Forks, Deer Lodge, and Piedmont and passing tracks at other points. Seven of the substations designed to supply power for the first half of the 440 miles of route were completed and electrical equipment practically installed.

Work on the construction of the forty-two 282-ton locomotives was at that time progressing rapidly. The first complete locomotive was placed on a test track early in September, 1915. In November, 1915, it had been turned over to the railroad company and was being exhibited at various points on its route from Chicago to the electrified division of the St. Paul. On November 13, the St. Paul made a test of one of the new locomotives on the tracks of the Butte, Anaconda and Pacific, as power was not yet available on the St. Paul.

Fig. 4. East Portal Substation with Operators' Bungalows, C., M. & St. P. Station Contains Three 2000-kw. Synchronous Motor-generator Sets

On December 9, the Chicago, Milwaukee & St. Paul trans-continental "Olympian" was taken from Butte, Mont., to Piedmont by an electric locomotive, and on December 8 officers and directors of the road and officers of the General Electric Company made an inspection trip over the line in a fast train consisting of three special cars and one electric locomotive. The test consisted of operation at various speeds up to 70 miles an hour, with various tonnages. On December 9, two electric locomotives took a train of 48 loaded cars, 3,000 tons, from Butte up the two per cent grade to the summit of the Rocky mountains at a speed of 15 miles an hour and then continued down the descending grade on the opposite side. This was the inauguration of electric operation. It was not until January, 1916, however, that steam freight locomotives were entirely removed from the electrified division.

At about that time it was found that the electric locomotive could handle considerably more tonnage than the builders guaranteed, and it was also demonstrated by the various tests run during that period that the system of regenerative braking was entirely successful.

During the month of April, 1916, service was extended to Harlowton, Mont., making a total of 220 miles of electrically operated road. On November 1, the St. Paul put in operation the third electrified district, the line from Deer Lodge, Mont., to Alberton, a distance of 110 miles. This made the total length of line electrified, Harlowton to Alberton, a distance of 336 miles. On December 11, 1916, 76 miles were added to the electrified section which completed the electrification from Harlowton, Mont., to East Portal at the east end of the St. Paul Pass tunnel, making a total distance under electrical operation of 406 miles. During this month (January), the finishing touches are being put on the last 25-mile stretch of electrified district, and it is expected that the entire mountain division of 440 miles will be electrically operated by February 1.*

* The complete electrification of the 440 miles from Harlowton to Avery went into operation at noon on February 24th when electric trains began operation through the mile and a half St. Paul Pass Tunnel at the summit of the Bitter Root Range. —EDITOR.

PHASE TRANSFORMATION

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The derivation of balanced polyphase power from a single-phase source of energy, without the use of rotating apparatus,* has been for many years greatly desired by engineers. Considerable interest should therefore be created by the following article which demonstrates how both voltage and current at quadrature with a single-phase source of supply can be obtained by means of inductance. However, by this method it is not possible to derive a balanced polyphase system, because in each case where quadrature power is derived there is always an excess of power delivered in one phase, so that the system is unbalanced. Although no attempt is made to suggest any practical application of the principles involved, this article will be found very instructive and interesting to those who wish to understand the mechanism by which an inductance can store energy and deliver it dephased from the original source of power.—Editor.

One of the most difficult problems connected with alternating-current phenomena is the derivation of polyphase currents from a single-phase circuit.

Since the power consumed in a true polyphase circuit is continuous, whereas the power given by a single-phase circuit must be pulsating, it follows that the single-phase supply circuit cannot transmit all of the power direct to the polyphase circuit, but that some form of storage of energy is necessary wherein part of the power coming from the single-phase circuit is temporarily stored and is turned over at the proper time to the polyphase circuit. Then the power that the polyphase circuit draws direct from the single-phase supply circuit and the power that the polyphase circuit draws from the storage may be made to superimpose so as to give a continuous flow of power. This, as is well known, can be accomplished by the use of rotating apparatus or by the simultaneous use of inductance and capacity.

This article describes a very interesting method of connections which attacks the problem by the use of only inductance and mutual inductance, and it involves a rather novel application of the transformer. Fig. 1 shows these connections.

The lines a and b are the conductors of a single-phase supply circuit, across which the electromotive force E is active. T_1 and T_2 are two windings, each with a different number of turns, wound on the same core of a transformer, which will be called the "phase transformer."

We will limit our study to the case of a non-inductive receiving circuit, as this scheme of connections (in its present form) is not applicable to inductive loads. The ohmic resistance r_1, which is in series with the winding T_1, and the ohmic resistance r_2, which is in series with the winding T_2, are the active

* A motor-generator set, comprising a generator and a motor each equal in capacity to the power delivered, has been the only practical means by which this conversion could be made. Recently, however, the size of the rotating apparatus has been very much reduced by the development of Mr. Alexanderson and others, by which the rotating apparatus handles only a fraction of the energy delivered.