ECONOMICS OF ELECTRIC RAILWAY DISTRIBUTION.*

By Horace Field Parshall, D.Sc.

PRACTICALLY all modern traction systems of the larger class are referable to the same class of power house and transmission system, and these are not affected to any important extent by the sub-station arrangement, which is determined with reference to variations in the operating result occasioned by the spacing of the capacity of the individual sub-stations.

In the book by Mr. Hobart and the author on "Electric Railway Engineering," most of the problems entering into the design of electric railway installations have been dealt with. The question of the economic arrangement of sub-stations and the distribution conductors was not dealt with at length, because at the time the book was written sufficient operating data were not available to furnish a basis for different calculations. Such a wide difference of opinion existed between different engineers as to the cost of operating and maintaining a system of sub-stations that it did not appear advisable to treat the subject except on general lines. Since the publication of that book a great deal of experience has been gained, as a result of which engineers have come into more general agreement as regards sub-station practice. The present paper is written with a view to assist towards the standardization of electric railway sub-station practice. Many years ago Lord Kelvin formulated a law as to the economic use of conductors in transmission systems. The number of independent variables when a complete system with sub-stations has to be dealt with is so great that the mathematical expression, from which might be deduced the minimum cost, would in practice be open to some suspicion. In this paper a complete balance-sheet embodying every item has been worked out for each case, and the tabulated result is included as a part of the paper; hence, for different conditions it would be possible for an engineer to make the necessary corrections, so that, without any great amount of labor, the methods and results of the paper may be applied to practically any class of electric railway installation. The paper has not been extended to include the electric traction installation as a whole, since the process of standardization in respect of motor equipments is still proceeding, and conclusions that might be drawn under present conditions would in another short time be incorrect. So far as the distribution is concerned, the conclusions are likely to be lasting, since the operating conditions on which the general results are founded are likely to obtain for a considerable time to come.

With the given energy-consumption per unit of length of line that follows from a given train-movement, the capacity of the substances increases indirectly with the distance between them. The energy-loss in distribution-conductors of a given section varies with the cube of the distance between sub-stations. The cost of attendance is within wide limits independent of the size of the sub-station. The cost of the plant per kilowatt falls off with the size of the units, but the maintenance and renewals per kilowatt are more or less constant. The paper embodies a series of curves showing graphically the arrangements of substations that will operate different train services on different electrical systems and at various voltages with a minimum total operating cost. With rotary-converter sub-stations and a working voltage of 600 volts, and for certain assumed average conditions of train-weight, speed, and energy-consumption, the most economical sub-station spacings are 8½, 5½ and 3¼ miles for train services of 6, 12 and 24 trains per hour respectively. For a working voltage of 1,200 volts the sub-station spacings are 11, 7½ and 5 miles respectively, while when 2,400 volts is adopted the most economical sub-station spacings are 16, 12 and 8½ miles for the three train services respectively. Curves are also given illustrating the advantage gained by working at higher voltages, and these confirm the author's view that with the present arrangement of rotary-converter sub-stations, there is little advantage in a higher voltage than 2,400 volts for the track conductor. The economy of higher voltages is shown to be approximately the same whatever the train service. As between 600 and 1,200 there is a saving of 14 per cent. in the total annual costs of the distribution system; as between 1,200 and 2,400 volts there is a further saving of 7 per cent., or 21 per cent. as between 600 and 2,400 volts. If the working voltage is further increased to 3,600 volts, there is a decrease in total annual expenditure on sub-station and overhead conductor equipment of only 3 per cent., which will be less than the additional cost of the rolling stock.

For single-phase distribution at 5,000 volts the most economical sub-station spacings are 31, 24 and 16 miles for train services of two, three and six trains per hour respectively. At 10,000 volts single-phase, the most economical sub-station spacings are 45, 34 and 26 miles for the same three train services respectively. With three-phase distribution at 5,000 volts the most economical distances between sub-stations are 38, 31 and 18 miles for the same respective train services. In most of these last cases, however, the economical distance between sub-stations thus determined is greater than would be permissible in practice from considerations of both traffic operation and voltage drop. Further, in the case of single-phase operation, the lower pressure of 5,000 volts is found to be the most economical for certain services and the higher pressures of 10,000, 12,000 and 15,000 volts in vogue on the continent are explained by considerations of voltage drop.

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POWER SURVEY OF CANADA.

The Commission of Conservation is compiling data respecting power used in the Dominion. A circular has been issued to power users and manufacturers requesting information regarding the consumption of power. The questions asked cover the field fully, embracing water power, electric power, steam power, gas engines, and oil engines, and each division solicits answers which, if given with any degree of enthusiastic co-operation, should place the Commission in the position of being able to compile information that will be found of great value by Canadian engineers and manufacturers. It is to be hoped that those to whom blanks have been sent will furnish the fullest possible information and that any of our readers who may not have been approached by the Commission, will apply for a blank to the Assistant to Chairman, Commission of Conservation, Ottawa. The compilation entitled "Waterworks of Canada," published in December, 1912, has proved of signal value, and it is to be expected that the data which the Commission has now set itself the task of collecting, will have an even greater field of usefulness throughout the country.