# ECONOMICS OF POWER TRANSMISSION LINES.

The following is an article by Mr. Alfred Still, engineer at the Magpie mine, Michipicoten District, Ontario, which was printed in a recent issue of Western Egnineering. It will be remembered that we published an article by Mr. Still entitled "Steel Towers for Overhead Transmission Lines" in our issue of October 10th, 1912.

"True engineering is based on economics." These are the words of R. D. Mershon; and every engineer does or should realize the truth of the statement. On the other hand, there are many engineering undertakings, or portions of such undertakings, in which this fundamental principle has been disregarded. In the case of transmission lines a certain system, or an exceptionally high pressure may have been adopted because of its peculiar interest as an engineering problem; or duplicate lines, spare generating plant, and costly automatic gear may have been installed to ensure continuity of supply, apart from the economic value of such increased protection against possible interruption. This, however, is not engineering in the commercial sense. The determination of the economical size of conductors for the transmission of any particular amount of current, in accordance with the principle generally known as Kelvin's law, is now well understood; but this is a very small part of the problem to be solved by the transmission line engineer. An attempt will be made in this article to deal with the economics of the overhead power transmission line from a broad practical standpoint. Some approximate figures for use in getting out preliminary estimates will be given, and in the working out of any numerical examples it will be assumed that the principles governing the selection of the most economic size of conductor require no explanation. When considering any scheme of power transmission from a generating plant of limited output, it is important to bear in mind that it does not pay to cover distance greater than that within which there are reasonable prospects of supplying all the power available at the generating station. The importance of this principle should be fairly obvious; yet there are instances which prove that it has been disregarded.

**Choice of System.**—On this continent it is usual to transmit electric power by means of three-phase alternating currents, the periodicity being 25 or 60 cycles per second. In Europe the Thury system of continuous current transmission at high voltages has met with success; it has much to recommend it, and there appear to be no reasons why it should not meet with equal success on this continent; but it is probable that three-phase transmission, at pressures even higher than those now in use, will hold its own for a considerable time to come.

**Type of Transmission Line.**—The structures for supporting the overhead conductors may be of wood, steel, or reinforced concrete. The wood supports may be of the ordinary single-pole type spaced 100 to 300 ft. apart, or they may be **A** or **H** frames built up of two poles suitably braced, and capable of supporting longer spans. The steel poles may be of the simple tubular type, or built up of three or four vertical tubes or angles. The more common construction for high-pressure transmission lines consists of light-braced towers with wide rectangular bases, except where the "flexible" type of structure is adopted. These flexible towers are modeled generally on the **A** and **H** types of double wood pole supports. It is by no means an easy matter to decide upon the most suitable type of supporting structure to be used on any particular transmission scheme. In some cases a composite line including two or more types of support may be found advantageous. Among the factors influencing the choice of the supporting structures may be mentioned the character of the country, the means and facilities of transport, climatic conditions, the nature of the soil, and the scarcity or otherwise of suitable timber in the district through which the line will pass. In undulating or hilly country, advantage may frequently be taken of the heights, by erecting upon them comparatively low and cheap structures and spanning the depressions or valleys without any intermediate supports. The engineering features must, however, be very carefully studied in all such exceptional cases.

**Length of Span.**—Even when the type of structure has been decided upon, the height, strength, and cost of the structures will be dependeent upon the distance between them. The determination of the average length of span is indeed a very important economic question. The material of the conductor will, to some extent, influence the choice of span length, because aluminum conductors will usually have a greater summer sag than copper conductors, and this will necessitate higher supports to give the same clearance above ground at the lowest point of the span. In considering span length, the first cost of the individual support is not the only question which has to be taken into account; the cost of maintenance is almost equally important. The longer the span, the fewer will be the points of support; and if the line is well designed and constructed, there should be less trouble through faults at insulators. Again, where rent has to be paid for poles placed on private property, it is generally the rent per pole apart from the size of pole which has to be considered, and this is another factor in the determination of the best length of span. In level country, the economic span for steel tower construction is usually in the neighborhood of 550 ft. If substantial, braced, wooden towers of considerable height are used in a district where such structures can readily be constructed, the economic span would probably be greater than 600 ft. It is hardly necessary to mention that, when comparing costs of various kinds of supports, the relative life and cost of upkeep of the poles or towers must be taken into account.

**Effect of Span Variations on Cost of Steel Towers.**—The height of towers in level country depends on (1) the minimum clearance between the lowest conductor and ground when the sag is greatest; (2) the voltage, since this has an effect on the spacing of the conductors and also to some extent on the clearance above ground level; and (3) the maximum sag. This last is determined by the lengths of span, the material and size of the conductors, the range of temperatures, and weather conditions generally. For the purpose of rough approximations suitable for preliminary estimates I have made use of the empirical formula

$$H = 35 + 0.3\ V_k + 0.6\ \left(\frac{l}{100}\right)^2 \quad (1)$$

This gives the approximate overall height of towers in feet. The voltage Vk is expressed in kilo-volts and the length of span l, in feet. The formula is especially applicable to towers carrying a duplicate three-phase circuit. The constants have been worked out on the supposition that there are six No. 0000 aluminum conductors and a grounded guard wire joined to tops of the towers. It is not intended to apply to spans greater than 600 ft. In the case of larger spans advantage is usually taken of inequalities in the ground levels. The cost of steel towers will depend not only upon