### Complete Plan.

The engineer should provide a complete plan showing the whole of the work as carried out. In the case of sewers the plan must show the correct position of each manhole with it. depth, the gradient of each line of sewer as laid, with all junctions for future connections correctly marked with measurement of distances from manholes.

This now concludes what can only be looked upon as a very scant and general survey of a big subject. The author feels that he has gone over much ground which is by no means new to the engineer experienced in public works. The object however has been to put the whole subject in a concrete form, of some value to municipalities and others who may be contemplating works as described, as a new venture.

## GENERATING END OF POWER STATIONS.

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As soon as the generation end of the power station comes into consideration, it is necessary to go to the other end of the line and study the field of work to be fed by the station, as surely the nature of the load must determine the characteristics of the generating units. If the power development is to be one of any great magnitude, it will usually be designed to do general work, including street and commercial lighting, electric railway service and the factory power business, thus carrying a direct load, as well as a synchronous and inductive load.

Up to the present time the larger part of electrical power has been generated by continuous current. All the earlier plants are of this type, and even now, when generation by alternating apparatus, polyphase or other, is generally used, the older type of apparatus is still being installed on an extensive scale. New power plants, both here and abroad, are, save for rare exceptions, for alternating currents, and in many cases this practice is absolutely necessary. But there still remain many cases where the conditions are well met by direct current. Chief among these may be mentioned railway work, where certain difficult works at variable heads and loads are at present best handled by direct current machinery.

As a general statement, we may say that for an area not exceeding two miles square, with the power house reasonably near, the centre of the load and the service, ordinary lighting and power, a direct current, three-wire system, operating at 220 volts across the outside wires, may be used with good results. On this 110-220 volt system we may operate incandescent lamps, constant potential arc lamps, and motors with good efficiency. Where a large portion of the load is to be motor load, it is usually found desirable to use an E.M.F. in the neighborhood of 550 volts. For railway work, aside from single-phase systems, 550-660 volts are used in standard practice. With this voltage the maximum distance to which energy can be distributed with economy is from six to seven miles, which distance is too great if the amount of power delivered is large.

With more extended territory, it is necessary to pass to one of two schemes if satisfactory and economical service is to be given. The first of these is to use two or more power plants, operating either singly or in multiple, each serving a territory within suitable limits for the low potential direct current used. This at one time was very common practice, but there is only one combination of conditions under which it should be used, namely, when the load is quite dense and uniformly distributed. Even under these most favorable conditions the efficiency of this plan is not nearly as high as that of the more up-to-date plan outlined below.

This plan, common in all practice to-day, is that of having a central station, and to make use of the higher voltage alternating current for distribution and transmission, transforming this to a suitable voltage and to D.C. where necessary for the receivers. The reason that one large station with transformers and sub-station is preferable to several central stations is that the large station can be operated more economically on account of labor, and because larger and more efficient units may be used, the same being loaded so as to operate at or near maximum economy. If direct current, three-wire systems are still required in certain districts, they are fed from synchronous converters.

(1) But if an alternating supply is found desirable, there still remains the question of selection of voltage, frequency and number of phases, as well as the detailed method of distribution. The principal factor in determining the transmission voltage is the length of the proposed line. If the field is near at hand, a low voltage may be desirable, even as low as 10,000 volts, or in special cases 6,600 volts. Under these conditions, step-up transformers are unnecessary, for a machine voltage up to 11,000 is entirely within the limits of good practice. If, however, many miles of line are required, the transmission voltage should not be lower than 22,000, or preferably 33,000 volts. Perhaps 66,000 volts would be better to meet all conditions. Of course, with any voltage, possibly above 10,000, step-up transformers would be an absolute necessity. As a rule, it is not advisable to have the generator voltage above 22,000 volts unless the generator is to have a very large capacity, say, over 2,000 k.w.

(2) In selecting the size and number of generating units for the central station, the amount of the load to be carried at different periods of the day must be known, and this is best expressed in the form of a load curve representing the average conditions at the period of the year when the load on the station is high. Such load curves are calculated or estimated for a period somewhat in advance of the time when the machinery is installed, usually about three years, so that additions to take care of the increase in load do not have to be made immediately after the first installation. The load curve gives the minimum and maximum demand upon the station. The total capacity of the generating units should be sufficient to safely carry the maximum demand as shown by the load curve, and there should be a reserve capacity sufficient to allow any unit to be laid off for repairs without interfering with the service. The smallest unit should be selected, so that it will carry the minimum load without running for long periods lightly loaded. If the prime mover is one having a high efficiency at light loads as well as at full loads this point is not so important. On the other hand, large units are desirable on account of lower first cost per k.w., decreased floor space required and increased efficiency at normal load. If made too large, either we must sacrifice some reserve capacity, or the normal rate of the plant will be high compared with the actual demand upon it. The size of individual units for the very large stations has increased very considerably with the introduction of the steam turbine.

A uniform size of unit is desirable for the first installation and the reserve capacity may be in the form of an extra unit, or it may be in overload capacity of the generator installed to carry the maximum load when operating at or near normal rating. To illustrate, suppose our curve shows a maximum of 2,000 k.w. and a minimum of 350, the maximum load lasting an hour, the minimum load five hours. We may select four 500 k.w., and three of these will carry the maximum load when overloaded 33 per cent., thus allowing any one to be laid off for repairs. If the installation for regular operation is made up of two 500 k.w. units and a 1,000 k.w. machine, then a fifth unit must be added for reserve, and this could be a 500 k.w. machine. With four or more units the reserves can usually be in the form of overload capacity if the machines are used in regular service. For fuller extension of the plant, the machines may be of larger size, always keeping in mind the question of reserve capacity. A theoretical basis for determining the size of machine added one at a time is k.w. capacity of new unit = previous capacity of the plant × per cent. overload allowable.

(1) F. Osgood, A.I.E.E., April, 1907.

(2) Geo. Shood, Standard Handbook, p. 528.