AMERICAN POWER TRANSMISSION.*

A REVIEW OF RECENT WORK.

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MUCH of the power-transmission work of the last five years or so has been of an unobtrusive character, mere extension without material change of what had gone before. In many instances, indeed, there was no need of innovation since the common voltages and types of apparatus proved perfectly adequate. As time has gone on, however, the tendency has been to use higher and higher voltages. The prevailing high prices of copper have served to stimulate this tendency of late, so that the use of moderate voltage, say 10,000 to 14,000, derived directly from the generators, has declined, and even for relatively short lines the voltage is frequently raised by transformers to 20,000 or more, the generators themselves being commonly wound for 2,000 to 2,500 volts.

In fact, the use of generators for more than this moderate figure is now rare in the ordinary hydro-electric transmission plants, and is chiefly confined to steam plants serving large lighting or electric railway systems in which the use of underground cables acts as a limitation on the practicable voltage.

On the other hand, the voltage of transmission in ordinary practice has been steadily rising, not by sensational leaps, but by steady progress, until at the present time one can scarcely classify anything short of 30,000 volts as of really high voltage, and double this figure is reached in something like a score of cases. In two notable plants, the Grand Rapids-Muskegon system in Michigan, and the Kern River line of the Los Angeles (Cal.) Edison Company, the working pressure is now approximately 75,000 volts, and the security of the service is sensibly as great as in the plants working at 50,000 to 60,000 volts. It is probable that within a year this limit may be raised to 100,000 volts or more, since at least two plants now under construction are being equipped for such working. Nearly all high-voltage transformers are equipped with one or more taps on the high-voltage side, so that they can be worked at 5 to 10 per cent below their full voltage, and in many cases plants start up with the raising transformers connected in mesh and afterward gain assurance and pass to star connection and full voltage. The use of composite three-phase transformers is rapidly increasing as experience has been gained in transformer insulation, and this is the common type in high-voltage work on any considerable scale. There is no serious difficulty in providing transformers for 100,000 to 150,000 volts, or even higher pressures, and the possible advance in voltage depends directly upon line insulation.

Heretofore the factor of safety in the insulators has been rather unsatisfactory. It is easy to get porcelain of good quality but difficult so to design the structure as to gain security against surface leakage. When an insulator is dry and clean its power of holding up against extreme electrical strains depends chiefly on its external dimensions—i. e., on the distance which must be jumped by a discharge from the wire over the edges of the petticoats to the pin. In wet weather, and particularly in a driving drizzle, its power of resistance depends almost entirely on its ability to preserve enough dry surface in the interior to check surface leakage, since a wet surface is a conducting surface. In dry weather a big insulator with flaring petticoats may prove entirely dependable and yet fail entirely under a searching rain. Insulators with deep and narrow crannies between the petticoats are better under a wet test, although they may give trouble when dust storms are frequent. Of the two 75,000-volt American plants one (in the dry California climate) is on large pin-type insulators, with moderately flaring petticoats, while the other is chiefly on the later type of suspension insulator.

In this type several porcelain bells, either plain or with concentric petticoats, are strung together like a series of Japanese gongs, the uppermost being carried by the cross-arm, the lowest supporting the wire. The bells themselves are all of the same size, ranging from 10 inches to 15 inches in diameter, and are fastened together by metallic links variously held in position. In the simplest form the bells are channeled as in some strain insulators, and the linking wires loop through each other from above and below, holding the porcelain in compression between them.

Insulators of this sort are used with two to five or more bells in series, and are undoubtedly capable of enduring high voltages far better than any pin-type insulator yet designed. It is very difficult to find any pin-type insulator that will stand 100,000 volts in

a driving spray for even a few moments, and even the best of them generally will flash over at 80,000 to 90,000, while even so few as three bells in suspension will hold 100,000 volts during a long "wet test." The two projected lines mentioned are being equipped with the suspension insulator, which appears to be the chief recent improvement in high-tension transmission.

Late constructions have been developed in the direction of reducing the number of supports by lengthening the spans. Moderately long spans on both steel and wooden poles have, of course, been used, but the Guanajuato transmission line in Mexico initiated the plan which has since been extensively followed. This line was carried in spans of 500 to 600 feet, on steel windmill towers, and while great trouble was experienced at first with the insulation, improved forms of insulator have made the plan thoroughly practicable. Most recent American lines have followed it and with fair success, although there has been a tendency to use too light and unscientifically designed towers which have occasionally failed and are of dubious life. For economy two complete circuits have often been run on the same towers, a precarious practice, as is evidenced by the fact that most such lines have simultaneously lost both circuits in case of any really serious difficulty.

The American tendency to use so-called "standard" stuff for cheapness has until recently prevented scientific design of pole lines as mechanical structures, but there are now signs of improvement in practice which will eventually promote economy of material.

As a whole, the American high-voltage long-distance transmission lines perform very well, but there are unquestionably more brief suspensions of service than most operating companies would care to admit. Foreign bodies falling upon or blown upon the circuits and lightning are the chief sources of trouble. Recent circuits are spaced widely, generally on the basis of about a foot for each 10,000 volts in the higher voltages, and hence escape many accidents of the former class, but lightning remains the thing most to be feared. Many circuits, especially those on steel towers, are equipped with a grounded wire strung above the circuit wires, which is supposed to deflect lightning discharges to earth. On some lines it seems to have been very effective, on others of small value. Probably a direct stroke of lightning upon the line would do damage in spite of it, while induced discharges would often be successfully averted.

An electrolytic lightning arrester composed of aluminium dry cells of large surface, stacked in series, has been recently introduced, and very fervent claims are made for it. Theoretically it promises well, but it has been nowhere long enough in use to enable one to speak confidently of its merits. Some of the most important systems depend almost entirely on the horn type of arrester of large dimensions, but most use elaborate forms of multiple gap arresters shunted to earth from several points.

In power-house design little of novelty is presented. The generators and transformers are in larger units than formerly, and the controlling devices are more thoroughly worked out. In fact, American engineers are making rather a fetish of switchboard apparatus, so that its cost has become very burdensome, and its complication introduces not a little risk of trouble from the enormous amount of wiring involved.

The frequency of late has remained unchanged on a general basis of 60 cycles, even for the longest transmissions. The two notable exceptions are Niagara at 25 cycles and the great network of the Los Angeles Edison Company at 50 cycles. Both these date from the early days of transmission, and have simply adhered to the original frequencies. The longest transmission is still upon the system in Northern California, 232 miles from De Saba to Sausalito, with the line from Niagara to Syracuse (N. Y.) a good second, at 165 miles, and several California lines not far behind. It is worth noting that there have been no material difficulties from the use of 60 cycles over the longest distances, and the long lines perform about as well as those much shorter.

The most interesting improvements in practice have been in the line of distribution. There is a strong tendency to unite a large group of hydro-electric plants into a single network whenever possible. Such great systems are to be found in Northern California, Southern California, Utah, and Colorado, to say nothing of many less complete examples elsewhere. The gain in continuity of service from the use of a network is very important, since serious interruptions are very

unlikely when each point can be fed from two or more directions. There is a great gain, too, in simplicity of the equipment, since each plant can be organized with the advantage of relying upon others. For example, a single water power can be utilized by one or two big generators and transformers depending on another power in case of breakdown, and yet not itself seriously affected by trouble in another plant on account of the cushioning effect of the long intervening circuits. It is quite certain that a group of moderate powers if intelligently developed can be brought into service more cheaply and can give more reliable service than a single plant of equivalent output organized in the usual manner and distributing power, like Niagara, chiefly along radii.

There is also the opportunity of utilizing in a single system hydraulic plants located on different watersheds and with different circumstances of high and low water so as to improve very greatly the conditions of hydraulic utilization. This situation has developed but slightly as yet, but it is highly promising.

In local distribution of power and light there have been some changes for the better. Most plants still depend mainly upon hand regulation, but of late some rather successful forms of automatic regulator for three-phase circuits have been brought out. The governing of the waterwheels, too, has been improved, and for the high heads the introduction of a successful type of needle valve has checked the waste incident to the use of deflecting nozzles for the impulse wheels. The palm for high head (920 meters) still rests with Switzerland, although the Rocky Mountain district furnishes some sensational falls.

In distribution work one interesting novelty has appeared in connection with a few transmission plants—the use of the so-called "magnetic" arc operated from mercury rectifiers. The arc itself gives an admirable light for out-of-door work, and the rectifiers, although of somewhat uncertain life, have been greatly improved and are fairly upon a commercial basis. In the main, American engineers still adhere to the alternating-current inclosed arc worked from constant-current transformers in spite of its poor efficiency as an illuminant.

Underground distribution is still unusual, and is in great measure confined to the old districts lighted by low-tension, direct-current mains. Now and then there has been a case of a high-voltage transmission taken underground from outlying districts to a sub-station, but the high-voltage cable problem is one that American engineers have never been called on seriously to face. High-voltage lines are run freely through well-settled country, and the risk has proved to be practically nil, since everybody knows that it is unsafe to meddle with the circuits, and the wires are so carefully erected that breaks are very rare and the grounded circuit is at once out of action. What few crosses of transmission lines with others have occurred have quite invariably been due to the shabby construction of the other circuits. With the steel construction now in vogue and insulators with ample factors of safety there is no material risk in using overhead transmission circuits of any voltage in almost any situation.

Linen fibers are usually distinguished from hemp fibers by the shape of the ends of the fibers; the linen fiber gradually tapers to a point, whereas the hemp fiber exhibits a blunt, rounded or knotty end. The sections of the linen fiber are polygonal while those of the hemp fiber are of more irregular outline. Hanau-seck treats the fibers with a solution obtained by adding an excess of sulphuric acid to a solution of potassium bichromate. In a few seconds the fibers begin to swell and the liquor near to the fibers turns green. Air bubbles appear and assist in causing the active yellow liquor to displace the now inactive green liquor around the fibers; this movement is further assisted by tilting the microscopic slide on which the fibers are resting. The linen fibers are found to swell more quickly than the hemp fibers. The surface of the fiber becomes irregular and dark patches are produced in both cases. These patches are seen to be more pronounced in the case of the hemp. Hanau-seck, however, attaches most importance to the appearance of the linings of the canals of the treated fibers. The canal of the immersed linen fiber is somewhat similar to that produced on treatment with cuprammonium solution; it is very narrow, wavy, irregular and broken. The canal of the hemp fiber, on the other hand, is a straight, continuous, very plastic tube, which is in no case broken or undulating.

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