est to have that one system which will the most readily lend itself to all of the work to be performed, for light, heat and power service. composite system may prove best suited, even in such short-distance transmission. That lighting service will, in general, be more satisfactory, and need not be more expensive, supplied independently of the power service. Direct and alternating currents are equally adapted for factory transmission, and by simple multi-circuit systems of distribution; that by two, three, or four-wire systems, as the case may require. Preferably, all distribution should be direct; that is, without the use of storage batteries, rotary converters, or transformers, except for certain lines of work in which it may be necessary to use one or the other of these indirect systems of distribution.

In the matter of voltages a wide range is possible: 110-volt two-wire and 220-volt three-wire systems for use of either direct or alternating currents for light and power; 440-volt two-phase alternating current three or four-wire systems for both light and power; 550-volt direct-current two-wire system, or 550-volt alternating current three-phase three-wire system, chiefly for power service, or the monocyclic system for both light and power. In general, it will not be necessary or advisable to use over 550 volts, direct or alternating current. Shocks arising from accidental contact with wires carrying currents of this voltoge are not necessarily dangerous. Experience has shown that workmen respect the distributing wires the higher the voltage. But it is not necessary to command such respect by raising above 550 volts.

ELECTRIC TRANSMISSION BY DIRECT CURRENTS.

At the time that electricity was introduced into manufacturing establishments the direct-current system was the only one available. For the peculiar and exacting service required in driving all kinds of machine tools and various workshop appliances, there were difficulties to be overcome with any system. It was necessary to secure satisfactory methods of producing a large starting turning moment, or torque, or varying the speeds as might be required under uniform or variable loads, and for reducing to a minimum the trouble arising from the use of a commutator.

With direct current motors, it was a simple matter to introduce starting boxes (resistances) in the armature circuit to control the torque, as well as rheostats (resistances) in the fields to control the speed in particular. But every such resistance meant an expenditure of energy in otherwise useless heating of the wire or other material of which these resistances might be made. The so-called Ward Leonard system came to the rescue with its two additional machines in order to operate the one given machine as a motor, at practically a constant efficiency under all conditions of load and speed. This system has been very successfully used extensively used in elevators, cranes, etc. By the use of the auxiliary machines the supply voltage may be varied according to the speed desired, and the current supplied according to the torque required, without wasting any energy in heating wasteful resistances. For conditions of factory service permitting of such an application, two motors may be advantageously used on one machine or set of machines, by means of which it is possible to vary the torque and speed quite as satisfactorily as in street-car working, by the series-parallel method fo control.

The difficulties with commutators have been almost entirely overcome and many refinements in design effected, so that the direct-current motor of to-day leaves little to be desired. Such objectionable features as still remain are inherent in the direct-current system used, and are found to lie chiefly in the kind of armature, commutator and brush devices required. These parts are most liable to derangement, require systematic attention for cleanliness and efficiency and renewals of brushes.

ELECTRIC TRANSMISSION BY ALTERNATING CURRENTS—INDUCTION MOTORS.

The alternating current system, with its induction motor service, offered practically the only alternative to those engineers and manufacturers who did not care to be troubled with the petty annoyances and delays likely to occur at any time with the direct-current motor. The induction machine as it stands to-day is probably the most perfect motor yet developed from the standpoint of electric transmission in factories and mills. It may be started and operated from any point at any time, at practically any load and speed within its predetermined ranges. It may be used on 110, 220, 440 or 550-volt alternating current circuits of one, two or three phases. It does not require any direct-current supply as the synchronous motor does for its field excitation. It does not require any brushes, commutator or collecting rings. Offsetting these advantages, however, are certain restrictions. The speed of an induction motor falls off slightly as the load is increased. The ability to start an induction motor from rest under a heavy load, as well as the possible speed changes during its operation, are obtained at some sacrifice of efficiency.

Induction motors, moreover, permit of higher lineal speeds than are possible with any other type, from 6,000 to 7,000 feet not being infrequent. By suitable arrangements of its field windings, this type of motor may have its speed altered in regular steps, so reducing it one-half, one-quarter, one-eighth, etc. This makes possible similar changes to gear-wheel combinations, which may therefore be eliminated to the extent that the induction motor is installed to effect such changes. In almost all cases of shop driving, the slip is not objectionable, any more than the increasing slip of the driving belt as the load is thrown on. These motors will stand almost any amount of rough usage and heavy overloads, as they cannot be burned out. If excessively overloaded, the motor slows down and stops, starting up immediately as soon as the load is lightened. Ordinarily, machine tools and almost all classes of shop machinery are started at quite light loads, and the full load is thrown on when the work or the tool is up to the speed desired. For this class of work the induction motor seems specially fitted.

A larger generating power pl[illegible]s required for an installation of inductior notors than would be the case if direct-current motors were used. This is on account of the energy which is lost in all classes of alternating current circuits in which there is considerable self-induction, whether in the transmission wires or in the appliances used. In the case of induction motors this loss is very appreciable at light loads, becoming much reduced at average and heavy loads, at which it is almost uniform.

SYNCHRONOUS MOTORS

Synchronous motors are admirably adapted to factory service where absolute uniformity of speed is required, and where the extra installation of a direct current supply for their field excitation is not deemed objectionable. While induction motors are always wasteful of some energy, through their high self-induction, synchronous motors may on the other hand be brought into that condition of operation practically equivalent to the use of direct-current motors, at least for a large range of their loads. In other words, the power factor of a synchronous motor may be made almost anything from zero to unity, according to the extent of excitation of its fields by the direct current applied for this purpose.

When made in the revolving field type, synchronous motors are self-starting from rest at light loads. They may be very heavily overoaded, without falling out of synchronism or out of step, and when they do for an instant they may be brought back again by throwing off some of the load. A well-designed synchronous moter will carry at least three times its full normal load, and not drop out of step. If an induction motor is built for such overloads it is likely to have quite low efficiency at ordinary loads.

Higher efficiencies may be obtained with synchronous motors than with induction motors of the same output. In fact, such motors realize the ideal conditions of motor working in which the motor attains almost the same efficiency as the generator. Both induction and synchronous motors have usually higher efficiences than direct current motors of same size.

COMBINED INDUCTION AND SYNCHRONOUS MOTOR WORKING.

The ideal conditions in a factory installation no doubt would be secured where both induction and synchronous motors were used, the former for small machines and direct driving, the latter for operating a set or group of machines. The synchronous motors would be started up just before beginning the work of the day, have at all times a light constant load, and might easily be regulated as to produce an almost balanced system in combination with the induction motors. In such a system of transmission the lagging currents of the induction motors would be offset by the leading currents of the synchronoas motors, if the latter were operated to produce such leading currents. The whole system would be operated practically throughout quite a range or load variations, as if it were a simple direct current system. the advantage of such a condition is apparent; it means least installation for any given output, or greatest output for any given capacity of of generating plant. The group method of electric driving is much better adapted for small machines, up to and including 2-horse power capacity, and especially where such machines are in almost constant service. Above this size, individual motor driving becomes more and more efficient, particularly if the machines are operated only a fraction of the day.