For example, if a generator is designed to give a terminal voltage of 115 at no load and 125 at full load, it should give 120 at half load. If the voltage at half load were 122, the regulation would be 2/125 = 1.6 per cent. The term regulation as applied to constant speed motors refers to speed, and is the maximum percentage variation from the full load speed.

**Distributing Systems.**—The earlier systems of distribution, which were used principally for lighting, consisted of two wires, between which, as far as possible, a constant potential of 50 or 100 volts was maintained. This system is still in use, and is quite suitable for small, isolated plants not exceeding 100 horse-power, where no

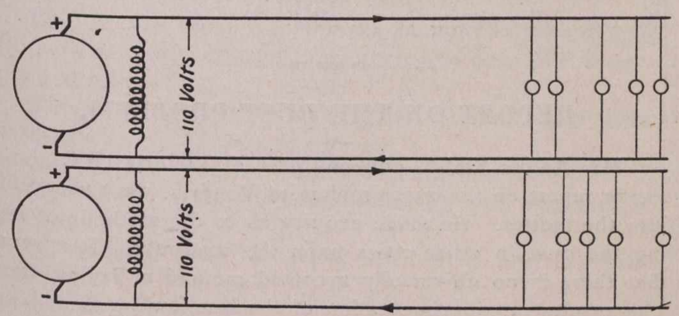


FIG. 45

large amounts of power have to be transmitted over distances exceeding 500 feet. With this system the lights and other apparatus are connected in parallel as shown in Fig. 44. As the demand for electric lighting increased, the distance over which current had to be carried also increased, and to avoid an excessive cost for transmission wires or an excessive loss of power if the size of wires were limited, it became necessary to increase the voltage of the system. The first step in this direction was to combine two of the "two-wire" systems to form a "three-wire" system as shown in Figs. 45 and 46. In Fig. 45 two 110 volt two-wire systems are shown running side by side, but independent. In Fig. 46 the negative or return wire of one system is combined with the positive

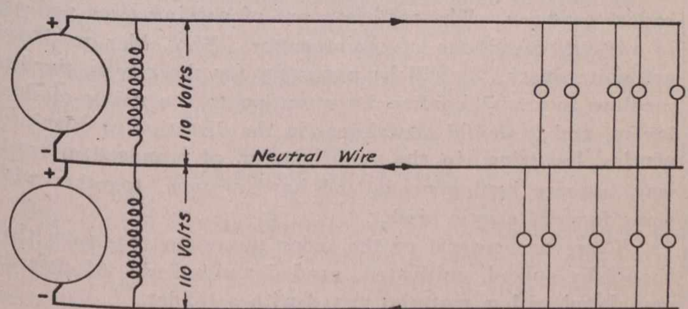


FIG. 46

wire of the other system. As the currents in the wires when separate run in opposite directions, it follows that when the two are combined the resultant current is equal to the difference between the separate currents. If the number of lamps lighted on each of the separate systems were equal, there would be no current in the middle or "neutral" wire when the two systems are combined, and the whole of the current would flow under a potential of 220 volts. In actual operation, however, the number of lamps lighted on each side is never the same at any one time, and it is, therefore, necessary to have the neutral wire to maintain the same voltage between the terminals of all the lamps. Without this wire the voltage would always be too high on the side with the smaller number of lamps and too low on the other side. As the difference between the number of lamps which are usually lighted on either side at one time may be kept within narrow limits, and as the current flowing in the neutral is only equal to that required by the excess of lamps on either side, the capacity of this wire may be limited to about 25 per cent. of that of the outside wires, for in a properly designed system the excess of lamps or load on either side should not reach even this amount. This applies only to circuits of large capacity where a reduction in the size of wire means a considerable saving of copper. In the case of branch circuits of small capacity it is usual to make the wires all the same size.

When a single generating plant is to supply power for lighting purposes, and also for motors or other apparatus of large capacity, it is usual to run separate transmission lines directly from the station to supply such apparatus independently of the lighting circuits. In the case of a three-wire system these "power" circuits may be two-wire or three-wire. The latter are used only when it is desired to vary the speed of large motors over a considerable range. The purpose of installing separate power circuits is to avoid the disturbance to lamps due to the varying voltage drop caused by the large momentary currents taken by apparatus of large capacity, especially when starting. In addition to avoiding such disturbances, a larger voltage drop may be allowed on the power circuits than is allowable on lighting circuits. This point will be referred to again in connection with the calculation of transmission lines.

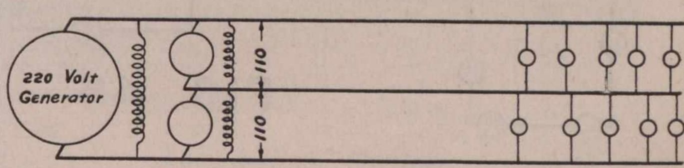


FIG. 47

When the three-wire system was first introduced two separate generators working in series were used, as shown in Fig. 46. At the present time such systems are operated by a single machine designed to give a terminal voltage equal to that of the two separate machines in series, and the voltage between the outside wires and the neutral is maintained at a constant value by means of a "balancer," as shown in Fig. 48. This balancer consists of two 110 volt shunt motors (or generators), the shafts of which are direct connected, and the armatures of which are connected electrically in series. The terminals of the combination are connected to the outside wires of the system, and the neutral wire is joined to the connection between the two motors. When the number of lamps in use on either side is the same, the system is said to be "balanced," and in this case the two motors will run idle, each generating 110 volts, while the current passing through the armatures is just sufficient to overcome the friction. If, however, there is an excess of lamps in use on one side, this balance of voltage is destroyed, the voltage tending to rise on the side with the smaller number of lamps and fall on the other side. This will cause the motor on the side with the higher voltage to speed up, while the motor on the other side becomes a generator. Thus it will happen that half of the current flowing through the neutral wire will pass through one of these machines working as a motor, and the other half