

1 In power plants having two or more alternators, parallel operation is an everyday act. When two machines are synchronized some indication is needed to show when generators are in step, so a voltmeter, lamps or a synchroscope is used

What the Synchroscope Does

Voltage, frequency and phase rotationship must match when alternators and systems are synchronized. James Wilson, electrical engineer, tells how one instrument sums up all values except voltage. He explains the operating principle of several synchroscopes

▶ IN AN ALTERNATING-CURRENT power plant with more than one generator, the essential instruments are voltmeter, ammeter and synchroscope. There are also some helpful but not indispensable assistants like the wattmeter, power-factor indicator and frequency meter. Before considering the synchroscope, let's glance at the functions of voltmeter and ammeter.

Voltmeter and Ammeter. To hold correct voltage, every plant must have available at least one voltmeter. In addition, each generator must have an ammeter to measure output current because the amount determines the heating of the machine. The heating in turn limits the total load that can be safely carried.

Most power plants, for over-all economy and operating continuity, have more than one generating unit. To carry the common load, these units are usually operated in parallel. This operation, to be satisfactory, requires generators of similar electrical characteristics and prime movers with speed characteristics that are alike.

Alternators in Parallel. Two polyphase ac generators, to parallel, must have equal voltages, frequencies that match, the same phase rotation, and proper phase relationship. Phase rotations are set equal at installation, and the process is called "phasing out." An ac voltmeter indicates voltages, but a check is also needed to determine when they are reaching maximum values in an individual cycle. This last test can be made with either lamps or voltmeter, but values are not so good with either medium as with a synchroscope.

The only definite indication given by either lamps or voltmeter, Fig. 1, is that the incoming alternator is passing the point of synchronism—or is in step. If the lamps are connected so they are burning at the point of exact synchronism — *synchronizing bright* — the eye cannot distinguish the instant of maximum brilliancy. For the method called *synchronizing dark*, the dark period is shorter than the bright. Yet the eye cannot tell the exact point of no-current through the lamps, which is the point of synchronism.

If the voltmeter is used on the equivalent of synchronizing bright the indication, properly interpreted, is better than with lamps. If the voltmeter is connected for the equivalent of synchronizing dark, the point of synchronism is not clearly indicated because its pointer is at zero on the insensitive end of the scale. Synchronizing bright with either voltmeter or lamps requires a special transformer except on low-voltage systems. The synchronising-dark method with voltmeter, lamps or synchroscope, can use the same potential transformers provided for the regular metering. This additional load is applied only during the synchronizing period, and does not affect the instruments' accuracy for metering.

Synchroscope Operation. To parallel one ac generator with another, the synchroscope clearly indicates every condition that the operator needs to know except exact voltage. Although this instrument usually has only a single mark at top center and *Slow* and *Fast* with an arrow above each word, it shows whether the incoming generator is running at the same frequency as the bus or the other generator but not in synchronism with it. The synchroscope also shows whether the incoming generator is running slower or faster, or whether the generators are in synchronism. By the term synchronism—in step—we mean that incoming generator and bus are at the same frequency, and that voltage alternations of both have the same value and polarity at the same time.

These indications give information for the preliminary operations of paralleling a generator with a running plant, and enable the operator to close the generator switch without shock to the system. This is particularly important on lower-frequency steam-turbine plants since a small error causes large swings of power to pull the incoming alternator into synchronism. These swings place unnecessary electrical and mechanical strains on equipment.

Although synchronizing lamps are not really necessary, many plants install them in addition to a synchroscope. They burn brightly when the pointer is at the bottom and dim gradually as it moves toward the top mark, where the lights are completely dark. In this way, the operator has a constant check on the synchroscope and its connections.

Synchroscope operation depends on one of the following methods: (1) Split-phase bipolar synchronous motor with ac excitation, Fig. 2, 3, 4, 5 and 8. This type works by a 2-phase split of one of the synchronizing voltages. (2) Vane actuated by a resultant flux, Fig. 6 and 7. This method works by a 3-phase split of both synchronizing voltages. (3) Electrodynamometer movement, Fig. 9, similar to a wattmeter's. Methods (1) and (2) are applications of the rotating field.

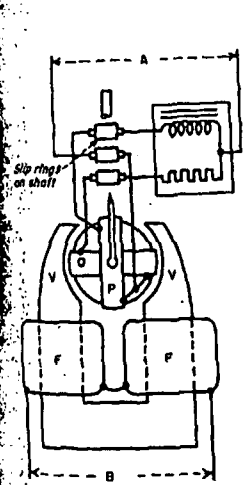
Rotating Field. The split-phase bipolar synchronous motor with ac excitation and the rotating armature is one of the oldest types of split-phase synchroscopes, Fig. 3. Its operating principle is comparatively easy to demonstrate. The rotating armature is energized by circuit *A* through coils *P* and *Q* in series with a reactor and a resistance respectively. Coil *P* circuit is highly inductive, due to the external reactor, causing current in the coil to lag nearly 90 deg behind the voltage of circuit *A*. Coil circuit *Q* with its external resistor, is but slightly inductive so current in that coil is very nearly in phase with the voltage of circuit *A*. The equivalent of a true 90-deg current difference for these armature coils is obtained by shifting them slightly from a true right angle to each other. This produces a smoothly rotating magnetic field in the armature structure, and causes the pointer to show the true phase relationship between circuits *A* and *B*.

Circuit of coils *F* is highly inductive because of the iron field poles, and its current is nearly 90 deg behind the voltage of circuit *B*, whose magnetism is oscillating in value, and fixed in position in relation to poles *V*.

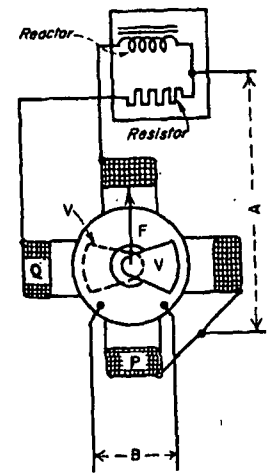
The armature rotating field coincides with that of the field poles, holding the armature and its pointer. Thus they move clockwise or counterclockwise at a rate corresponding to the difference in frequency of circuits *A* and *B*. If frequency of the circuits is the same, the pointer comes to rest at the posi-



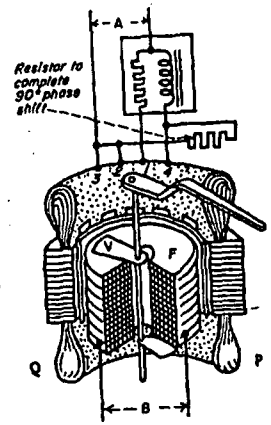
2 This disassembled view of an iron-vane synchroscope uses a stationary 2-phase armature with distributed winding. The vane is actuated by the resultant flux.



3 Split-phase rotor and bipolar synchroscope with a revolving armature



4 This stator combines an armature and field windings; both stationary



5 Distributed winding on the stator with a phase-shift circuit is shown