Westinghouse

Alternating-Current Generators and Synchronous Motors

INSTRUCTION BOOK

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works East Pittsburgh, Pa.

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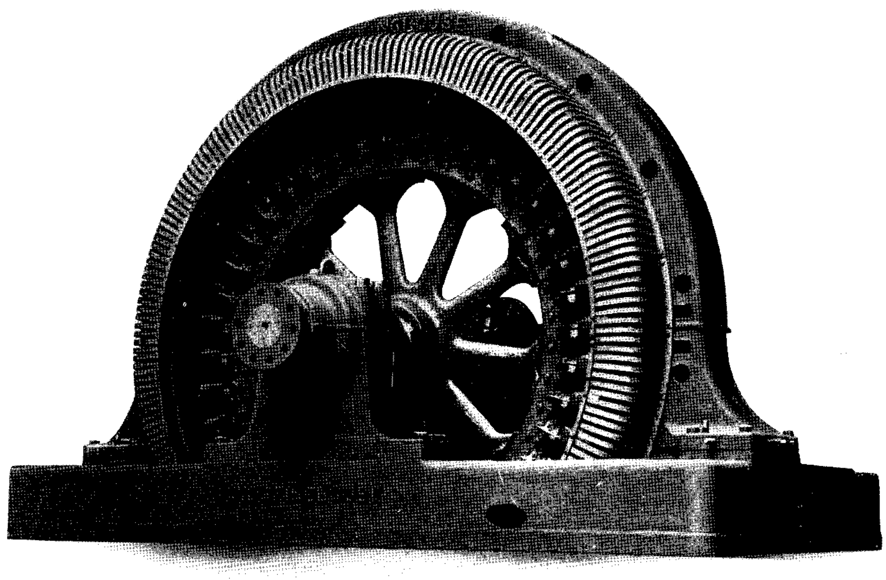

Coupled Type A-C. Generator, 2300 Volts, 2000 Kv-a., 3-Phase, 60 Cycles

INDEX

CAUTION

Keep the generator clean. The finest machines and the most expensive plant may be shut down by accident if they do not have protection and care. The insulation must be kept clean and dry. Oil and dirt in the insulation are as much out of place as grit or sand in a cylinder or bearing. In a direct-connected unit oil may splash from the driving machine or work along the shaft to the insulation and cause a burn-out unless the attendant provides the necessary protection.

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Alternating-Current Generators and Synchronous Motors.

General Information

CHARACTERISTICS

Types—Westinghouse standard alternating-current generators and synchronous motors are of the separately excited type with stationary armature and revolving field. They are divided into the following classes:

Belt-driven type, having two or three bearings, shaft and pulley.

Coupled type, having one or two bearings with shaft arranged for direct connection to the driving machine, either steam or hydraulic. The frame may or may not be provided with a bedplate.

This class includes generators of the turbine type, specially designed for direct connection to steam turbines. For these machines the bearings are not provided by the generator manufacturer.

Engine type, consisting of complete field and armature without bearings or shaft, the revolving field being mounted on the extended shaft of the steam engine or other prime mover. The yoke may or may not be provided with shoes, or shoes and slide rails.

Excitation—The exciting current for the field of Westinghouse standard alternators may be supplied from any suitable direct-current circuit. The exciting electromotive force is 125 volts, unless otherwise specified.

INSTALLATION

Location—It is very important that the location of an alternator be wisely chosen, due regard being paid to the rules of the National Board of Fire Underwriters and to local regulations. Wherever possible the following considerations should govern the choice:

(1) The generator must be located in a dry place and not exposed to moisture. All fittings below the machine must be tight, so as to prevent moisture or escaping steam from reaching the windings.

(2) The machine should not be exposed to dirt from coal handling, or other causes.

(3) It should be placed in a cool and well ventilated place, as any increase in the temperature of the engine room is added to that of the generator.

(4) A generator must never be placed in a room where any hazardous process is carried on, or in places where it will be exposed to inflamable gases or flyings of combustible material.

Caution—**Never support the revolving field wholly or in part by the collector rings,** either when raised by blocking or when held by a rope sling. Lift the field by a rope sling about the shaft. Do not allow workmen to stand on the rings.

Use kerosene to remove paint on the journals. In cases where rust is present use an oil stone or emery cloth and finish with an oil stone, depending upon the amount of rust to be removed.

Do not mar or scratch the shaft, as any roughness may cut the bearings and cause them to run hot. The rotating field of a large generator which must be pressed on the shaft in the station should be supported when possible on the spokes of the spider by passing heavy timbers through the spider and blocking up to them at each end. When this is impossible, it should be set in a cradle, cut out of heavy timber to fit and lined with excelsior or waste, so that the weight will be evenly distributed over a large area of the core. This cradle should be made narrower than the core in order not to injure the winding. A field so supported should be braced on both sides.

Foundations—Solid masonry or concrete makes the best foundation for heavy machinery. A generator not exceeding 50 kva. in capacity may be supported by a framework of timber. Other types of machines require heavier foundations and should be secured by foundation bolts set with a template made according to a drawing or blue-print of the generator base or bedplate, which will be furnished on application.

For turbo-generators the instructions of the Westinghouse Machine Company for foundations for turbine units should be consulted and followed.

Unpacking—If the coils of the machine have been exposed to a low temperature their coverings should not be removed until they have had sufficient time to attain a temperature nearly as high as that of the room in which they are to be unpacked. Otherwise when opened, they will "sweat".

Grounding of Frames—Grounding of the generator frame is recommended. If the frame be insulated from the ground the strains of the insulation of the windings will be decreased but danger to the attendants will be increased. If such insulation is desired, the foundation should be capped by a stout wooden frame bolted to the masonry, care being taken that the bolts are so placed that they do not make electrical contact with the bolts which secure the generator frame to the wooden cap, or with the frame itself. This wooden cap may be covered with some insulating waterproof paint or compound.

Engine Type Generators have their rotating parts of necessity grounded through the driving machine and piping. The stationary part may be insulated, but to do so requires special work and such insulation is not essential.

Erection of Belted Generators—(1) Set the frame in position, level it, and insert the bearings, if they are separately shipped. If the generator has a split frame, follow the same procedure with the lower half frame.

(2) See that the bearings and oil reservoirs are clean and free from dirt. Place the rotating part in its bearings.

(3) Clean the contact surfaces of both halves of the frame, dressing down the burs and rough edges to insure a perfect magnetic joint. If split frame, set the upper half in position and secure to the lower half by the field bolts and feather keys.

(4) Accurately align the shaft of the generator with the driving shaft, with the center lines of the pulleys directly opposite.

(5) Place the belt in position and run slowly.

If the shafts are parallel but the pulleys not directly opposite, the belt will run to one side of the larger pulley. If the pulleys are opposite but the shafts not parallel, it will run to one side of the smaller pulley.

(6) Secure the machine to its foundation. Some of the smaller alternators are shipped complete and need only to be set upon their foundations, leveled and lined up.

Erection of Coupled Type Generators— Proceed as in sections 1, 2 and 3, above.

(4) Align the generator shaft with the driving shaft and mount the coupling.

(5) Connect the coupling and run slowly; then secure the machine to its foundation.

Erection of Engine Type Generators—(1) The first operation in the assembly of an engine type generator is the placing of the rotating part and engine shaft in the bearings. With machines of large size the rotating part, usually the field, must previously be pressed upon the shaft in the station. In this case the first operation is the fitting of the hub to the shaft.

The shaft for an engine type generator is turned accurately to a certain gauge and the hub is bored out to a similar gauge several thousandths of an inch smaller, in order to secure a press fit. Before attempting to force the rotating part on its shaft, it should be gauged and the shaft calipered by an experienced mechanic and, if necessary, filed or scraped until it conforms to the correct gauges. The feather key in the shaft and the keyway in the hub should also be measured and fitted if necessary. The key should have a good bearing on its sides and should clear on top to $\frac{1}{32}$ of an inch. If the side of the key or way is not exactly parallel with the axis of the shaft, the pressure required to put the armature in place may be increased perhaps 30 per cent above the normal. In the larger sizes of shaft, from 16 inches up, the allowance for press fit is from .004 to .006 of an inch.

The pressure required to force the rotating part on the shaft varies with the temperature, condition of surface, and quality of the metal to such an extent as to make it practically impossible to estimate its value with any degree of accuracy. It is in general safe to assume that pressure of from 100 to 200 tons will be required for the allowance mentioned.

Before pressing the rotating part in place on the shaft, the bearing surfaces inside the hub should be painted with white lead and engine oil to prevent cutting the shaft.

When forcing a large rotating part on its shaft, it is preferable to use a hydraulic press. When this cannot be secured, make two yokes out of I beams. Set one of these in the rear of the rotating part and one at the end of the shaft, and draw the rotating part in place by means of two bolts which pass through the yokes and spider close to the hub. Care should be taken to tighten up evenly on the bolts; otherwise, the hub will twist and bind on the shaft. Once started, this operation should be carried to completion as quickly as possible, as, if the rotating part is allowed to set several hours when only part way on the shaft, it may require from 25 to 50 per cent more pressure to start than was previously used.

After the rotating part has been pressed upon the shaft it should be carefully lifted in a sling and lowered into its bearings.

(2) Set the bedplate in place and level up to proper position, i.e., to such a height as will allow room for one-half of the liners allowed for adjustment under the frame when the air-gap is correct.

(3) Set the frame in position and adjust, shifting it in a direction parallel with the shaft until its center line (half way between the ends of the laminated iron) is directly opposite the center of the rotating part (half way between the end plates which hold the laminations of the core). Then drill the bedplate for the guide rail.

(4) Cement the bedplate to the foundation, using a mixture of one part of Portland cement and two parts of sand, or half cement and half sand; either will give good results. First mix the cement and sand together, dry, and then add water until a very thin solution is obtained. Construct a dam around the bedplate and pour this solution under the bedplate, continuing the process until the cement stands about half an inch above the bottom of the bedplate. The entire operation of mixing and pouring the cement should be carried on without interruption and as rapidly as possible until completed, otherwise the cement first poured under the bedplate may partially set and prevent that poured later from flowing freely to all parts. When the cement has sufficiently hardened, remove the surplus from the outside and smooth up the joint under the bedplate. After the cement is hard tighten up the foundation bolts.

(5) **Adjustment of the Air-Gap**—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in adjustment of the air-gap between the armature core and pole faces, as any inequality in this gap will cause unnecessary friction and heating of the bearings and unequal heating of the armature iron. The unbalanced magnetic pull for $\frac{1}{32}$ of an inch displacement is usually given on the outline drawings of large machines. Adjust the air-gap horizontally by means of the cross beams and jack screws upon the bedplate, and vertically by means of thin sheet-steel liners between the bedplate and the yoke. During this operation gauge the gap at different points on the front and back of the machine by inserting a small metal or wooden wedge in the air-gap and noting the distance to which this wedge enters.

Connections—It is general practice to connect the main generator terminals to the switchboard bus-bars direct, without the use of protective devices such as fuses or circuit-breakers. The high armature reaction of alternating-current generators makes it possible to follow such practice without danger to the machines. Protective devices must not be used in the self-excited field circuit of composite wound machines. (See pages 20 and 21.)

MEASURING INSULATION RESISTANCES

It sometimes happens that the insulation of a machine is mechanically injured or exposed to moisture after the factory test but previous to erection. For this reason, insulation tests should be made before the machine is run.

The higher the resistance, the better the general condition of the insulating material. The insulating resistance of the field will be much higher in proportion to the electromotive force of the exciting current than that of the armature and will usually give little or no trouble. Since large armatures have much greater areas of insulation, their insulation resistance will be proportionately lower than that of smaller machines. Even though the material is in exactly the same condition, the insulation resistance of any machine will be much lower when hot than when cool, especially when the machine is rapidly heated. The only feasible way of increasing the insulation resistance when the machine is complete is by "drying out".

Insulation Test—In case a "meger" is not available insulation resistance measurements may be easily made using a 500-volt direct-current circuit and a 500-volt direct-current voltmeter. The method of measurement is

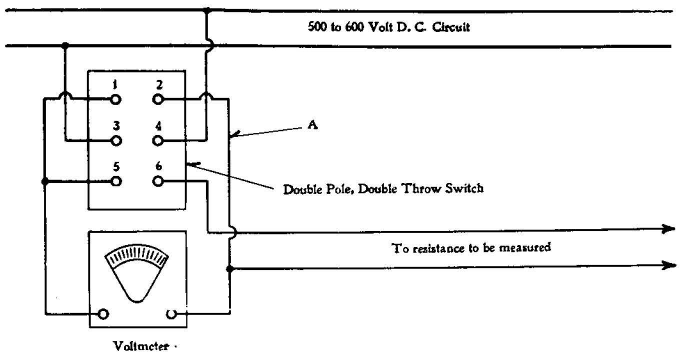


Fig. 1—Connections for Measuring Insulation Resistance

to first read the voltage of the line; then to connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance is then calculated by using the following formula:

$$R = \frac{r\ (V\text{-}v)}{v\ (1{,}000{,}000)} \quad \text{in which}$$

v =voltage of the line.

v =voltage reading with insulation in series with voltmeter.

r =resistance of voltmeter in ohms (generally marked on label inside the instrument cover).

R =resistance of insulation in megohms (1 million ohms).

The method of connecting the apparatus is shown in the diagram above.

If a grounded circuit is used in making this measurement care must be taken to connect the grounded side of the line to the frame of the machine to be measured, and the voltmeter between the windings and the other side of the circuit.

Voltmeters having a resistance of one megohm are now made for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified, since r= 1,000,000 and the above formula becomes

$$R = \frac{V}{v} - 1$$

A safe general rule is that insulation resistance should be approximately 1 megohm for each 10,000 volts applied in testing.

No machine should have an insulation resistance of less than 1 megohm.

Drying Out—If the generator has been exposed to dampness, before being started in regular service it should be run with its armature short-circuited beyond the ammeters and with the field current so adjusted as to raise the temperature to about 85 degrees Centigrade. The current should then be lowered and raised by means of the field adjustment until the coils become thoroughly dry. During this procedure the temperature should not be allowed to drop to that of the surrounding atmosphere, as the moisture would again then be condensed on the coils and the machine brought to the same condition as at the start.

There is always danger of overheating the windings of a machine when drying them with current, as the inner parts which cannot quickly dissipate the heat generated in them, and which cannot be examined, may get dangerously hot while the more exposed and more easily cooled portions are still at a comparatively moderate temperature. The temperature of the hottest part accessible should always be observed while the machine is being dried out in this way and it should not be allowed to exceed 80 degrees Centigrade, total temperature.

It may require several hours, or even days, to thoroughly dry out the machine, especially if it is of large capacity. Large field coils dry very slowly. Insulation is more easily injured by overheating when damp than when dry.

Insulation Test—During the drying out run, readings of the insulation resistance should be taken at regular intervals and plotted in curve form, using time as its seconds ordinates. In case the resistance shows a tendency to decrease at first, the drying should continue until the resistance reaches a minimum and has increased again to its proper value.

A high voltage or insulation test to ground is useful in determining the strength of the insulation of the machine. It is made by subjecting the insulation to an electromotive force greater than it will have to stand in actual service. As this test is of the nature of an over-strain, it must be applied with great caution. Such tests are always made in the factory and need rarely be repeated. However, when they must be made, it is well to remember that the insulation is more easily broken down when hot than when cool and that the test should not be made immediately after the machine is started the first time but after it has run hot for some hours and has been dried out. Tests of this character should not be made when the insulation resistance is low. See page 7.

Large machines, when tested at high voltage, require a considerable output from the raising transformer, as a heavy charging current may be taken by the machine. The transformer capacity required for testing varies as the square of the voltage of the test, as the frequency of the circuit and as the static capacity of the apparatus under test.

On machines of large static capacity due to distortion of the testing circuit wave form, the test voltage may be quite different from what the testing transformer ratio would indicate. For this reason the ratio should first be checked on all large machines as follows: Connect the testing transformer to the winding of the machine in the same manner as in making the regular test. Connect a needle point spark gap with a high resistance in series across the transformer terminal to the machine. Adjust the spark gap the distance given in the accompanying curve Fig. 2 to indicate the correct test voltage. Gradually raise the test voltage until the spark gap discharges the reading voltage indicated on the low-tension voltmeter, at the moment of discharge. Remove or increase the spark gap and make regular test for time specified bringing low-tension voltage to same value as noted on meter during calibration test.

In general a 5-kva. transformer has sufficient output for testing machines up to 500 kva. at a testing electromotive force of 6000 volts.

When making a high voltage test the **low-tension circuit connections** should always be used to throw the electromotive force off or on.

The severity of the test depends in a marked degree upon the time the electromotive force is applied. All breakdown tests are supposed to be applied for a short time only, as a long continued test is liable to permanently injure the insulation even if no immediate fault is developed.

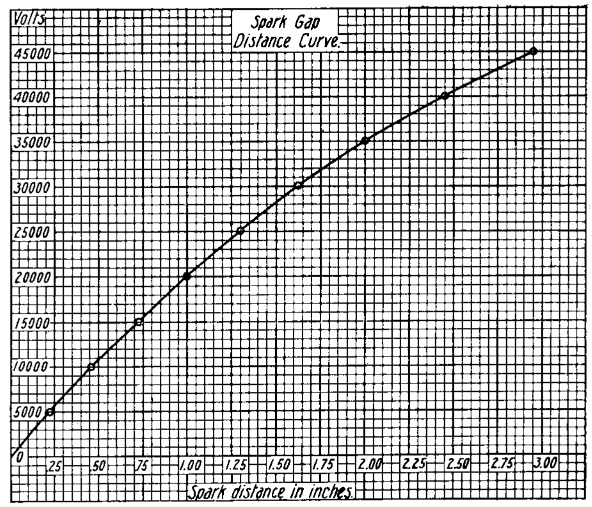


Fig. 2—Spark-Gap Testing Curve

High-Tension Wiring — Exceptional care should be taken in the running the lines of high-tension circuits. They should be placed as far as possible out of reach and where they will be free from danger of mechanical injury. All wiring should be installed in accordance with the rules of the National Board of Fire Underwriters.

OPERATION OF A SINGLE GENERATOR

General Precautions—(1) Leave all switches open when the alternator is not running.

(2) At all times keep the generator clean and free from oil and dust, especially from copper or carbon dust. With high voltage machines a small accumulation of dust on the windings may be the cause of a serious burn-out. In stations of sufficient size to warrant the expense it is advisable to install an air pump and blast, so piped that by means of a short section of hose the attendant may reach any part of the winding to blow out the dust. The pressure used in such service should not exceed 25 pounds per square inch, as a higher pressure may raise the insulation on the windings and blow dust inside the coils Always allow the accumulation of water in the pipes to be blown out before turning the air blast on the machine.

In water power plants where the type of

wheel is such that a vacuum is created in the tail pipe "vacuum cleaning" may be used.

(3) Keep small pieces of iron, such as bolts and tools, away from the generator.

(4) Occasionally give the machine a thorough inspection. The higher the voltage of the generator the more often should this be done.

Collector Rings—Precaution must be taken to keep the collector rings clean, smooth and true. To prevent cutting, a little clean oil should be applied occasionally.

Brushes—On the present types of alternating-current generators carbon brushes are used. Brushes should be given attention to see that they fit the rings properly.

Bearings—Westinghouse alternators have self-oiling bearings. The well should be filled to such a height that the rings will carry sufficient oil upon the shaft. If the bearings are too full, oil will be thrown out along the shaft. The oil should be renewed about once in six months, or oftener if it becomes dirty and causes the bearings to heat.

The bearings must be kept clean and free from grit. They should be frequently examined to see that the oil supply is properly maintained and that the oil rings do not stick. Use only the best quality of oil. New oil should be run through a strainer if it appears to contain any foreign substance. If the oil is used a second time, it should first be filtered and, if warm, allowed to cool.

A warm bearing or a "hot box" is probably due to one of the following causes:

(1) Excessive belt tension.

(2) Failure of the oil rings to revolve with the shaft.

(3) Rough bearing surface.

(4) Improper fittings of the journal boxes.

(5) Bent shaft.

(6) Use of poor grade of dirty oil.

(7) Bolts in the bearing cap may be too tight.

(8) End thrust, due to improper leveling. A bearing may become warm because of excessive pressure exerted by the shoulder of the shaft against the side of the bearing.

(9) End thrust, due to magnetic pull, rotating part being "sucked" into the field because it extends beyond the field poles further at one end than at the other.

(10) Excessive side pull, because the rotating part is out of center.

If a bearing becomes hot, first feed heavy lubricant copiously, loosening the nuts on the bearing cap; and then, if the machine is belt-connected, slacken the belt. If relief is not afforded, shut down, keeping the machine running slowly until the shaft is cool, in order that the bearing may not "freeze". Renew the oil supply before starting again. A new machine should always be run at a slow speed for an hour or so in order to see that it operates properly. The bearings should be carefully watched to see that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

Opening of Feeder Circuits—If a line fuse blows or a circuit-breaker opens, first open the switch corresponding to that line and then replace the fuse or close the breaker. After that, close the switch. If the circuit opens the second time, there is something wrong on the line—probably a short-circuit—and this should be corrected at once. If a short-circuit occurs at or near the machine, or if an arc be formed at a switch or fuse block and holds on, throw all resistance in with the rheostats. If necessary, open the field switch, and shut the machine down at once.

Starting—(1) See that the generator is clean and that there are no loose pieces of iron such as nuts, bolts or tools lying in close proximity.

(2) See that the bearings are well supplied with oil and that the rings are free to turn.

(3) Start slowly. See that the oil rings are revolving properly.

(4) Bring the machine up to speed and turn the rheostat so that all the resistance is in the field circuit, then close the field switch.

(5) Adjust the rheostat of the exciter for the normal exciting voltage; then gradually raise the alternator to its proper voltage by cutting out the resistance of its field rheostat.

(6) Throw on the load.

Causes of Insufficient Voltage—The following causes may prevent alternating-current generators from developing their normal electromotive force:

The speed of the generator may be below normal.

The switchboard instruments may be incorrect and the voltage may be higher than that indicated, or the current may be greater than is shown by the readings.

The voltage of the exciter may be low because its speed is below normal, or its series field reversed, or part of its shunt field reversed or short circuited.

The brushes of the exciter may be incorrectly set.

A part of the field rheostat or other unnecessary resistance may be in the field circuit.

The power factor of the load may be abnormally low.

Belts—The driving belt of a belted generator should be tight enough to run without excessive slipping, but the tension should not be too great or the bearings will heat. Belts should run with the lapping, not against it. The joints should be dressed smooth so that there will be no jarring as it passes over the pulley. The crowns of driving and driven pulleys should be alike, as "wobbling" of belts is sometimes caused by pulleys having unlike crowns. A wave motion or flapping is usually caused by slippage between the belt and pulley, resulting from grease spots, etc. This fault may sometimes be corrected by increasing the tension, but a better remedy is to clean the belt. A back and forth movement on the pulley is caused by unequal stretching of the edges of the belt.

Static Sparks from Belts—It sometimes occurs on belted machines, especially in dry weather, that charges of static electricity on the belt, which may be of quite a high potential, cause discharges to ground. If the frame is not grounded, these charges may jump to the armature or field winding and thence to ground, puncturing the insulation.

The belt and frame may be discharged by placing close to the belt, at a point near the dynamo pulley, a number of sharp metal points which are carefully grounded. If the field frame is grounded there should be no danger to the insulation.

To Shut Down—(1) Reduce the field current as much as possible by means of the field rheostat.

(2) Throw off the load by opening the feeder switches, or main generator switch if one be used.

(3) Open the separately excited field circuit.

(4) Shut down the driving machine.

(5) Wipe off all oil and dirt, clean the machine and put it in good order for the next start.

KINGSBURY THRUST BEARINGS

Packing and Rust Prevention—The bearing faces of the thrust collars (or runners) and shoes must be carefully protected against rust, corrosion or other injury, because any roughness may make the bearing run hot or burn out. In shipment or storage, those surfaces must be protected by some kind of neutral water-proof coating. Wood or damp packing material of any kind must not be placed in contact with them.

The best method of packing a collar (or runner) for shipment or storage is to bolt it into the box in such a way that the bearing faces are in no danger of touching the inside of the box. Very slight rusting of the bearing face may be removed by stoning with a fine oil stone, but if deep rusting occurs the surface must be refinished.

Babbitt faces of shoes are very sensitive to acid. Hence to avoid pitting they must not be packed in contact with paper, even if it is oiled. It is best to paint them all over with a neutral protective coating, placing two babbitt faces together and then wrap up the pair of shoes in weatherproof paper or case lining to keep out dirt and moisture.

Cleaning—Bearings and housings should be thoroughly cleaned before assembling bearing in place. Remove all anti-rust coatings with gasoline or kerosene. Use rags or cloth for cleaning, as waste always leaves lint, which may cause trouble in the bearing, or oiling system.

Bearing Faces—As the working faces of shoes and collars are fitted to a surface plate, they will fit each other very well when assembled in the bearing. This accurate fit is essential to the formation of the continuous thin oil film on which the working of the Kingsbury thrust bearing depends. Burrs, bruises and rust, caused by handling, shipment or storage, should be removed from all parts.

In order to detect and remove all small defects, the bearing face of the thrust collar (or runner) should be stoned lightly all over with a clean, flat face of a fine emery or carborundum stone and kerosene, rubbing back and forth in the radial direction (not circumferentially). Do not use a coarse-grained stone, nor scraper, nor file on the bearing face of the runner. The fine side of a number 121 carborundum oil stone is satisfactory.

Bruises on the wearing faces of the shoes may be removed with a scraper. The high spots may be found by testing them on a surface plate or on the bearing face of the collar. Remove any chips or grit that may be found embedded in the faces of the shoes.

Freedom for Self-Adjustment—Good operation of the bearing requires that the shoes and their supporting parts be free to adjust themselves to the collar position so as to overcome the effects of misalignment or springing of parts. Clearances for this purpose are provided in the designs. Before putting into service the bearings should be inspected to see that all parts are free as above described.

Keys, Dowels and Bolts—Special care should be taken to see that keys, dowels or bolts, used to fasten a thrust bearing collar or other parts to the shaft or housing, do not bottom or bind, as this will throw the parts out of true.

Removable Collars—Separate collars made in one piece are made a free fit on the shaft, and are usually held against a shoulder on the shaft by a nut. This shoulder must be machined true and square and must be free from bruises so that the collar will run true. The nut must be driven up very tight in order to prevent chaffing at the joints.

Removable thrust blocks, to which removable facing collars are attached, should be fitted to the shaft as above described.

Starting Up New Bearings—When shipped separately from the generator the bearings are carefully finished and boxed at the factory in the manner described above, but they are liable to injury thereafter from handling, improper re-boxing, dirt and bruises during shipment; hence, careful final inspection is necessary to be sure each bearing is in proper condition for operation.

After being run a short time, or after being turned slowly a few times, the bearing should again be inspected. If rubbing marks show excessive bearing pressures at any part of the bearing surfaces, the high spots should be removed by scraping. This process should be repeated until a good fit is secured. Streaks in the faces of the shoes may be caused by bruises or rough spots on the collar. Fine scratches may be due to dirt in the oil.

The ordinary installation will show a temperature rise of the oil in the thrust pot of about 15 degrees Centigrade to 20 degrees Centigrade. If any appreciable rise above normal temperature occurs, the machine should be shut down as quickly as possible and the cause of the trouble removed. If the trouble is detected early it can be corrected by scraping the babbitt to a new fit and stoning the collar, but if allowed to continue, the babbitt will be dragged off and more extensive repairs will be required.

In vertical thrust bearings, subject to practically full load at all speeds, repeated starts and stops may be made to improve the polish of the runner and the fit of the shoes. Practically no wear occurs except at the instants of starting and stopping; that is, when the oil film is not fully formed and the metals rub together. At these times the bearings when not rigidly mounted make more or less noise, like a grunt or groan, but this is normal and not an indication of trouble. When the bearing is in good condition and running up to speed the metals are separated by an oil film and there is practically no wear.

In general, it should be remembered that these bearings are very heavily loaded and should, therefore, receive more care and attention at first than ordinary shaft bearings.

Oil—The bearings will not operate properly unless the housing is filled with oil above the wearing surface, preferably up to the overflow. During erection, if it is desired to make a few turns of shaft for adjustment, apply a coating of heavy cylinder oil to the shoes. The service oil, unless otherwise specified, should be a good grade of dynamo or engine oil, free from acid, and having a viscosity of approximately 170 seconds at 40 degrees Centigrade (Saybolt test.) It should be kept clean and free from grit or other injurious substances, and where a "station" oiling system is used should be supplied returned to the bearing at a temperature not exceeding 35 degrees Centigrade.

Re-Babbitting Shoes—In case of necessity shoes may be re-babbitted, using genuine hard babbitt, preferably of the composition 85 per cent tin, 10 per cent antimony, 5 per cent copper, with proper care to prevent overheating in melting. Allow about 1/8 inch to machine off the face. Do not pene the babbitt. Face carefully and scrape to the collar face or to a surface plate

For shoes whose finished thickness must be

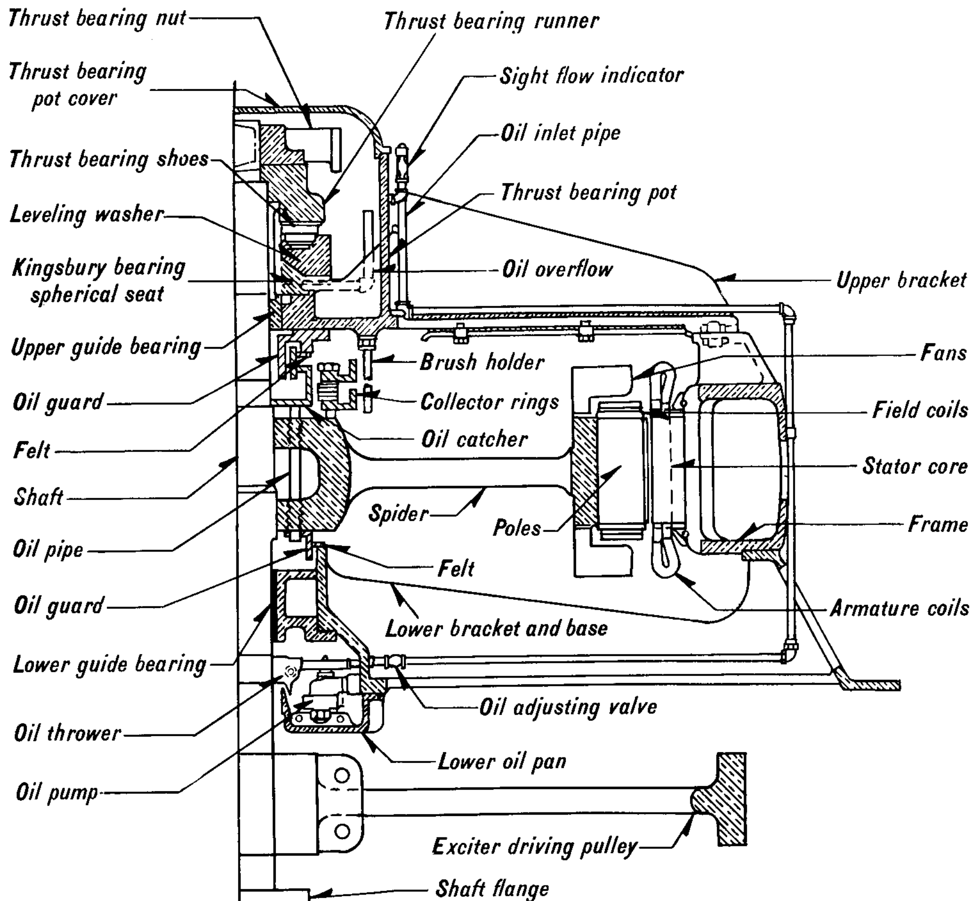


Fig. 3—Cross-Section of Type EV Generator Showing Arrangement of Oiling System

exactly the same, machine the babbitt to about .004 inch above gauge thickness, measured to supporting point on back of shoe. After scrapping final thickness may be adjusted by stoning the support point on back of shoe, measuring by micrometer or other convenient gauge. This precaution is essential when the bearing design provides a single rigid ring for holding the shoes.

When shoes are supported by adjusting screws, exact uniformity in thickness is, of course, not essential.

Bearing Current—Under certain conditions, depending upon the number of poles and the number of segment into which the armature punchings are divided, there may be a small voltage generated in the shaft. This voltage tends to circulate current through the circuit formed by the shaft, bearings and bedplate. If current is allowed to flow it will soon pit the shaft and bearing surface so that bearing trouble is likely to occur. For this reason a layer of insulation is placed between one pedestal and the bedplate on all machines which might otherwise develop bearing current. On vertical generators the insulation is placed between the frame and the upper bearing bracket.

It is important to see that there is no metal connection between the insulated parts which will permit current to flow. On a horizontal machine there must be no metallic connection between the insulated pedestal and the bedplate. On a vertical machine there should be no metallic connection between the frame and the upper bracket or the stairway or platform which are attached to the bracket The piping which comes in contact with the frame and bracket is furnished with insulated unions. Any additional piping or other equipment installed after erection of the generator should be put on with the same precaution.

Arrangements of Leads and Phase Sequence—Figure 4 shows various arrangements of leads on standard generators.

For three phase machines having three leads as shown in Fig. 4A the phase sequence, or phase rotation as it has sometimes been called, is in the order T_1, T_2, T_3 when the rotation of the machine is clockwise as viewed from the collector end. For counter clockwise rotation the phase sequence is reversed.

When the neutral lead is brought out it is located on the extreme right as shown by the lead marked T_0 in Figure 4B.

On some three phase machines six leads are brought out as is shown in Figure 4C. In this case either T_1, T_2, and T_3 may be used as main leads and the remaining three leads connected together for the neutral or the opposite arrangement may be used. That is T_4, T_5 and T_6 may be used as main leads and T_1, T_2 and T_3 used as neutral leads. In either case the phase sequence is from right to left with clockwise rotation.

When six leads are brought out as shown in Figure 4C, T_1 and T_4 are connected to the beginning and end respectively of one leg of the winding. Similarly T_2 and T_5 are connected to the ends of the second leg and T_3 and T_6 to the third leg.

A machine having six leads may be connected in delta in the following manner. Connect T_1 and T_6 together; connect T_2 and T_4 together; and connect T_3 and T_5 together. Three terminal leads can then be brought out from the three junction points.

A change from star to delta will lower the voltage to 58 per cent of its former value.

Figure 1D shows the arrangement of leads for a two phase machine. Leads T_1 and T_3 are connected to one phase and T_2 and T_4 are connected to the other phase. When rotation of the machine is clockwise as viewed from the collector end the phase sequence is in the order T_1, T_2, T_3, T_4.

While the sketches given here show horizontal machines the same arrangement is used for vertical units The phase sequence is from right to left when rotation is clockwise as viewed from above.

PARALLEL OPERATION

Determination of Relative Frequency and Phase Coincidence—The elementary principle of the method of determining when generators are of the same frequency and are in phase is illustrated by the diagram below, in which *A* and *B* represent two single-phase generators, the leads of which are connected to the bus-bars by the switches C, and through two series incandescent lamps. It is evident that as the relative positions of the phases of the electromotive forces change from that of exact coincidence to that of exact opposition, the flow of current through the lamps varies from a minimum to a maximum. If the electromotive forces of the two machines are exactly equal and in phase the current through the lamps will be zero and, as the difference in phase increases, the lamps will light up and will increase in brilliancy until the maximum is reached when the phases are in exact opposition. From this condition they will decrease in brilliancy until completely dark, indicating that the machines are again in phase. The rate of pulsation of the lamps depends upon the difference in frequency, i.e., in the speeds of the machines, and by adjustment of the governors the rate can generally be reduced to as low as one pulsation in ten seconds, which affords ample time for throwing the switch connecting the generators in multiple.

When the phase of two generators coincide the machines are said to be "in phase," "in step", or "in synchronism". The apparatus used for determining when generators are in phase is called a "synchronizer."

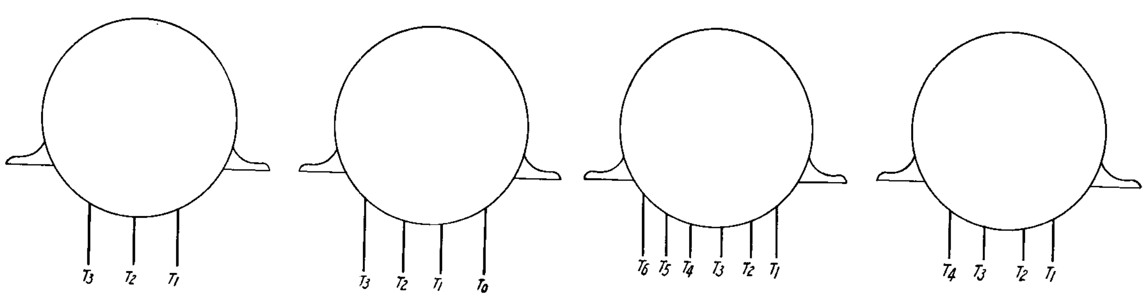


Fig. 4-A **Fig. 4-B** **Fig. 4-C** **Fig. 4-D**

Fig. 4

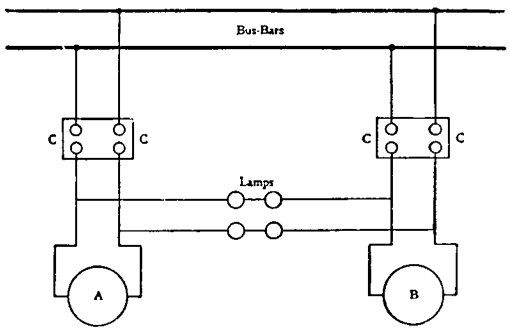


Fig. 5—Elementary Connections for Synchronizing Low-Voltage Single-Phase Generators

Synchronizing Single-Phase Alternators—An arrangement for synchronizing alternators in general is illustrated on Fig. 5, in which the lamps may be replaced by any synchronizing device. *A* and *B* represent two single-phase generators with switches in the main leads. There are two transformers, the primaries of which are connected across the main leads of *A* and *B* respectively, the secondaries being connected in series through the lamps. If the transformers are connected similarly in the two circuits (as shown in the diagram) when the generators *A* and *B* are in phase the electromotive forces in the secondaries will be in phase and no current will flow through the lamps. When the generators are out of phase, the electromotive forces in the secondary circuit will be out of phase also, and the current will flow through the lamps, the amount of this current and the resultant brilliancy of the lamps depending on the difference in phase. If the connections of either the primary or secondary of either transformer be now reversed from those shown in the diagram, the indications of the lamps will be reversed, i.e., when the generators are in phase, the lamps will burn at maximum

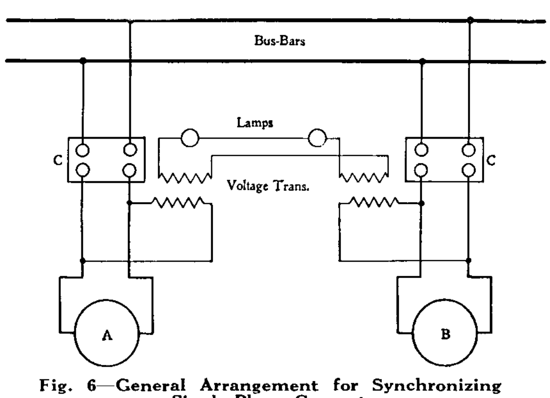


Fig. 6—General Arrangement for Synchronizing Single-Phase Generators

brilliancy and vice versa. Synchronizing with short connections is generally to be preferred.

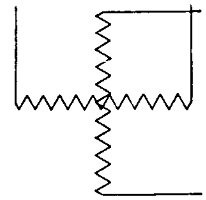


Fig. 7—Winding Diagram, Two-Phase, Open Coil Armature

In order to determine whether the synchronizing lamps will be bright or dark for a given connection of transformers when the generators are in phase, remove the main fuses from one machine, or disconnect the generator back of the shunt connection, and throw in the main switches with the other generator at full voltage. Since both primaries are now connected through the switches to one machine, the lamps will be in the same condition as when the main or paralleling switches are open and both generators are in phase. If the lamps burn brightly and it is desired that they be dark for an indication of synchronism, the conditions of one of the primaries or one of the secondaries of the transformers should be reversed.

The lamps should be adapted for the highest voltage which they will receive. Thus, if they are placed upon the secondaries of two 100-volt transformers, there should be two 100-volt lamps or four 50-volt lamps in series. If two 200-volt machines have the lamps applied directly without converters, then it will be necessary to use four 100-volt lamps or their equivalent.

Synchronizing Polyphase Alternators—What has been said in regard to synchronizing two circuits applies equally well to synchronizing the individual and similar circuits of polyphase machines.

In the paralleling of polyphase machines the location of the different circuits in the armatures and the connection of those circuits to the switches require special consideration.

Two-Phase Generators—When machines are to be run in parallel, the proper connection to the bus-bars is obtained when leads T_1 are connected to one bus-bar, T_2 to the second bus-bar, T_3 to the third bus bar and T_4 to the fourth bus-bar, provided all the machines are running in the same direction. If, however, some of the machines are running in the opposite direction, it is necessary to transpose the two conductors of one of its phase, say T_1 and T_3. It is always desirable, however, to test the connections in each case in accordance with the instructions.

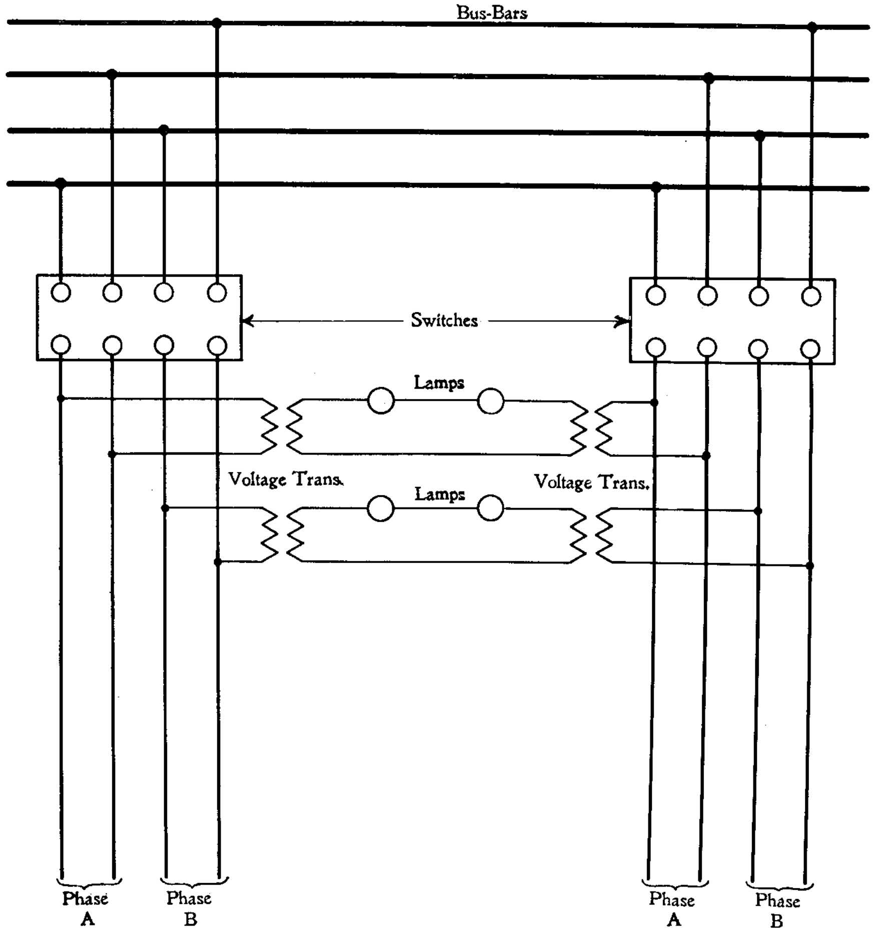


Fig. 8—Connections for Synchronizing Two-Phase Generators

The standard winding of Westinghouse two-phase armatures is of the open type with separate circuits. The two phases are electrically 90 degrees apart. Fig. 7 illustrates the method of connection.

As an illustration let it be required to wire two two-phase generators for parallel running.

Wire to the switches in such a way that the main circuits of machine *A* will go in parallel with the main circuits of machine *B*. These connections may or may not be correct for both circuits. In case they are incorrect, the electromotive forces of the two machines in one circuit will be exactly in phase when the electromotive forces in the other circuit are exactly opposed.

With apparatus of too high voltage to permit use of lamps, in order to determine whether or not these connections are correct it is advisable to connect a temporary synchronizing device in both phases. Such an arrangement consists of four transformers one in each phase, as shown.

For each circuit this arrangement is identical with that shown for synchronizing single-phase machines (Fig. 5). With one generator up to normal speed and voltage and the fuses removed from the other, the synchronizing device should be tested out separately, as previously described (pages 18 and 19), and, if necessary, the connections should be so changed that the lamps will be either dark or light as desired when indicating synchronism. Then both machines should be run at normal speed and voltage. If the lamps on both synchronizing sets glow and darken in synchronism the connections are all right. If, however, one set becomes dark and the other light at the same time, one phase will have to be reversed.

Some of the synchronizing transformer connections may then have to be changed, depending upon the place at which the changes were made in the main leads. It is therefore advisable, in order to guard against an error, to test out the synchronizing devices again and make the necessary changes in the connections so that all the lamps will be dark or light as desired when indicating synchronism.

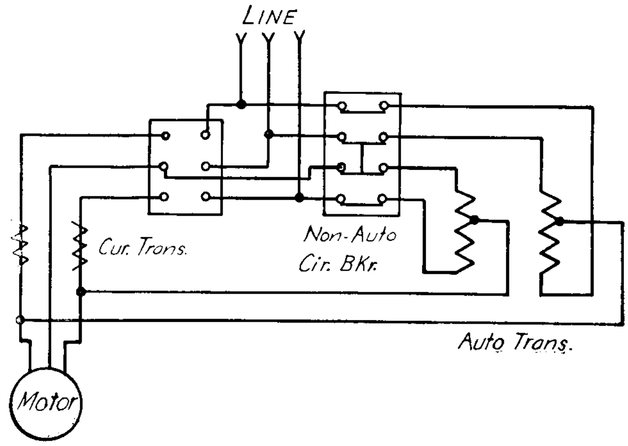


Fig. 10—Connections for Panel-Mounted Type QF Auto-Starter with Two-Breaker Starter Mounted Remote from Panel

Three-Phase Generators — Machines which are to be run in parallel should have lead T_1 connected to one bus-bar, lead T_2 to the second bus-bar, and lead T_3 to the third bus-bar, provided the direction of rotation is the same in all cases. If the rotation of any machine is different from the others, two of its leads, say T_1 and T_2, should be interchanged. It is best to test out each case according to instructions.

A star winding is almost always used on three-phase alternator armatures, as shown in the Fig. 9 on Page 17.

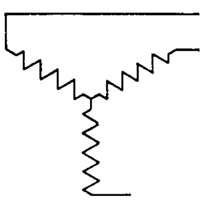


Fig. 9—Three-Phase Armature Winding Star Connection

Let 1, 2, 3 and *A*, *B*, *C* represent, respectively, the terminals of two three-phase generators, *D* and *E*. In wiring them to their switches connect them temporarily so that the phases of *D* will be in parallel with those of *E*. For example, connect phase *A-B* to 1-2; phase *B-C* to 2-3; and phase *C-A* to 3-1.

Connect synchronizing devices in any two phases, as phase

$\begin{cases} 1\text{-}2 \\ A\text{-}B \end{cases}$ and phase $\begin{cases} 2\text{-}3 \\ B\text{-}C \end{cases}$ Test out the synchronizer connections with machine *D* running at normal speed and voltage, the brushes or fuses removed from *E* and the paralleling switches closed. Having changed the connections of the synchronizer, if necessary, so that both sets of lamps will be the same when indicating synchronism, open the paralleling switches, replace the fuses or brushes of machine *E* and bring it up to normal speed and voltage. Then observe the two sets of synchronizer lamps. If their pulsations come together, i.e., if both sets are dark and both are bright at the same time, the connections are correct for paralleling the generators when the lamps are dark. If, however, the pulsations of the lamps alternate,

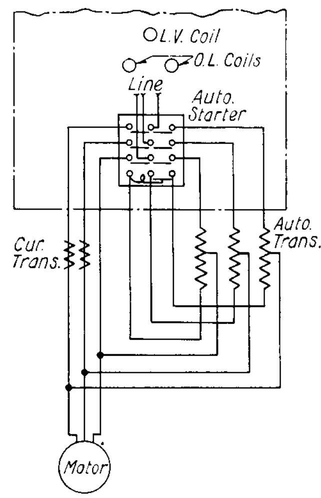


Fig. 11—Connection for Panel-Mounted Type QF Auto-Starter with 3-Phase Auto-Transformers.

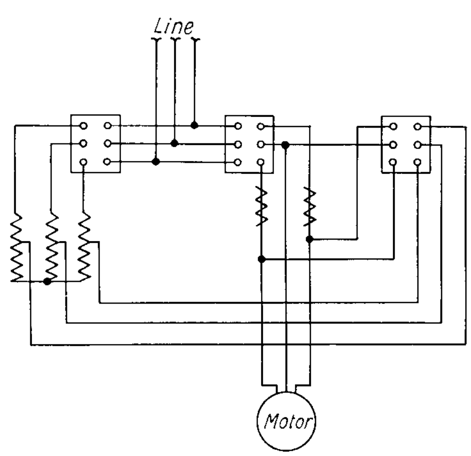


Fig. 12—Connections for Panel-Mounted Type QF Auto-Starter with Three-Breaker Starter Mounted Remote from Panel and with 3-Phase Auto-Transformers

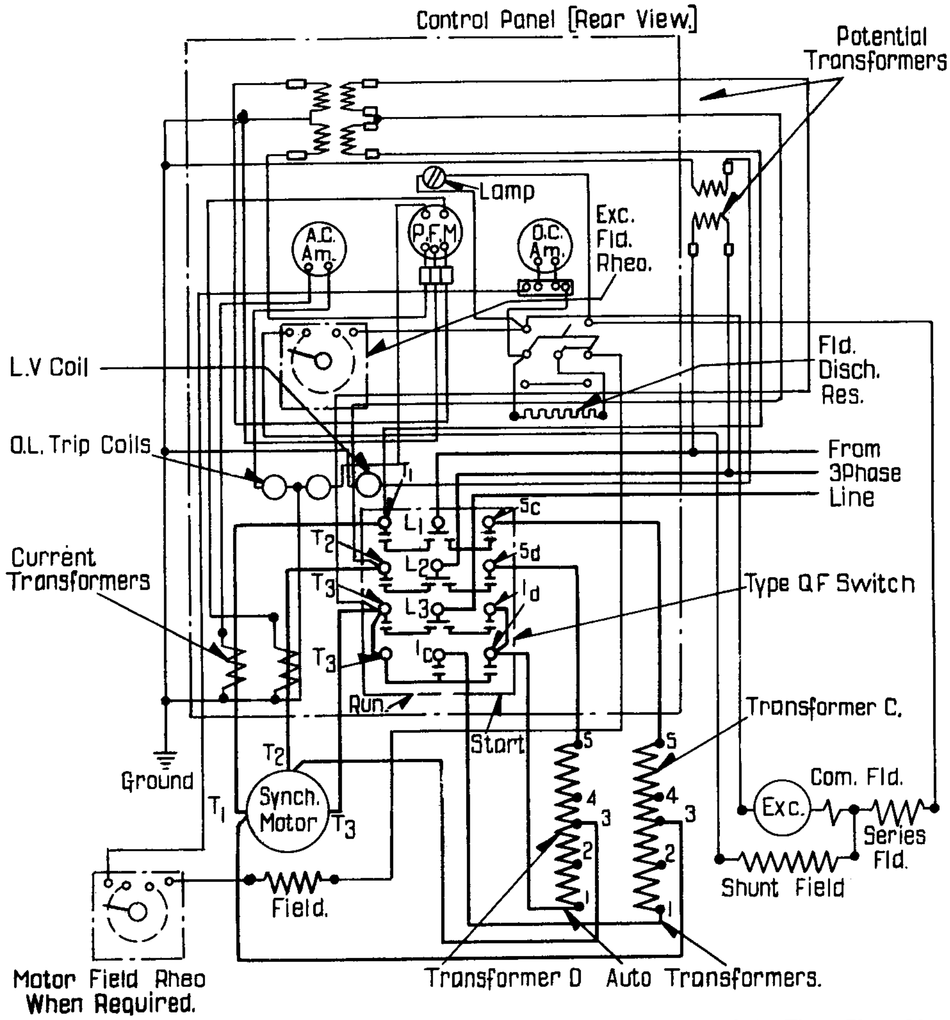


Fig. 13—Diagram of Connections—Synchronous Motor Starter with Type OF Switch for Three-Phase Motor. Fig. 16 shows a simplified diagram using previous style of power factor meter.

i.e., if one is dark when the other is bright, reverse any two leads of one machine and test out the synchronizer connections again, changing them if necessary so that they are the same when indicating synchronism. The lamps will now be found to pulsate together and the generators may be thrown in parallel at the proper indication. A synchronizer in one phase only will be sufficient for paralleling the generators after the first time.

In wiring three-phase machines for parallel running it will be noticed that two circuits only need be considered. This is evidently correct, inasmuch as any one circuit has its terminals in common with terminals of the other two circuits.

Synchronizer and Synchronoscope — Although lamps are quite generally used for synchronizing, the method is not safe practice for high-voltage generators nor wholly satisfactory for low-voltage machines, as there is always the possibility of throwing a machine in parallel with others when a considerable difference in phase exists between the respective circuits, inasmuch as the operator has no indication of phase difference other than by interpolating in a succession of lamp brightnesses. As such interpolation may be difficult and the results dangerous for the machine, a mechanical synchronizer is preferable.

The ideal synchronizer should perform three distinct functions:

(1) It should indicate whether the incoming machine is running too slow or too fast.

(2) It should indicate the amount by

which the incoming machine is too slow or too fast.

(3) It should indicate the exact instant of synchronism or coincidence in phase between the bus-bars and the incoming machine.

These functions are performed with perfection by the Westinghouse Synchronoscope. The instrument is provided with an indicator or hand which shows the phase difference between the machine and the bus-bars. This angle of phase difference is always equal to the angle between the pointer and the vertical position marked on the dial of the instrument. If the frequency of the incoming machine is higher than that of the bus-bars, this angle will vary, causing the pointer, if the instrument is properly connected, to rotate to the left. If the incoming machine is lower in frequency the pointer will rotate to the right. **Fast** and **slow**

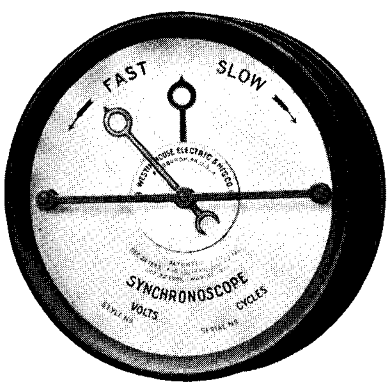


Fig. 14—Synchronoscope

on the dial mean that the speed of the incoming machine is too high or too low for the frequency of the bus-bars. When the frequencies are equal, the pointer stops at some position on the scale, and when the machine is in phase with the bus-bars the pointer coincides with the dummy pointer at the top of the scale.

The generator switch may then be closed. For further information see Ins. Tag. 26G on Westinghouse Synchronoscopes.

Starting—(1) Get the generator up to speed according to instructions on page 15.

(2) Adjust the electromotive force to correspond with the electromotive force of the bus-bars or the generators with which the incoming machine is to be connected.

(3) Synchronize; then close the main switch.

(4) Adjust the field rheostat to eliminate cross currents and the governors of the driving machines to properly distribute the load between the operating units according to their capacity.

Running Alternators in Parallel—GENERAL CONSIDERATIONS—If at any instant the electromotive force of one generator is lower than that of other machines with which it is connected in parallel, it will take current from the other generators instead of feeding current into the line.

That the electromotive forces may be the same at all times, the generators must conform in frequency, phase and wave form; otherwise pulsating currents will be set up. If similarly designed machines are adjusted for the same voltage and operate at the same uniform speed, these conditions are usually fulfilled.

Speed Adjustment and Regulation—The speeds of the driving machines should be adjustable while they are running in order that they may more readily be made to correspond when the generators are being connected in parallel and that the load may be properly divided.

When machines are operated in parallel there is sometimes a tendency to unequal speeds, which may be of several kinds.

(1) A tendency to two different speeds.

(2) Unequal speed regulation between no load and full load.

(3) Varying the speeds, such as would be caused by a hunting action on the part of the governors, giving rise to a surging of load between the machines.

(4) An irregular fluctuation of speed such as would be caused by lack of uniformity of velocity during a single revolution.

(1) DIFFERENT SPEEDS—If the governors on the driving machines give different speeds it is evident that when two machines are in parallel that which runs at the greater or higher speed will carry a greater proportion of the load until the speed is reduced, when the second machine will begin to carry the load. Before this condition is reached one generator may be running as a motor, as the tendency is for the speed to be higher than it would be if it were not running in parallel.

(2) UNEQUAL REGULATION—It is assumed that the governing of the speeds of the machines shall be such that when running at a common speed they shall receive their proper amount of

power. It is to be noted that machines governed closely between no load and full load may not be as well adapted to running in parallel as others in which the regulation is not so close. If two drivers regulate differently one will carry a much greater proportion of the load than the other.

In general, the power delivered by a generator which is running in parallel with other generators is dependent only upon the driving power, and not upon its field charge.

(3) Varying Speeds—If the governors give varying or irregular speeds it sometimes happens that first one machine and then the second will carry the greater load. The rapidity with which this change takes place depends upon the rapidity with which the governors oscillate in their running action. A slight irregularity of this kind may not produce objectionable interference with the service but, if carried far, results may be disastrous.

This tendency to varying speed, resulting in changes of position of the governor, is one of the most common sources of difficulty in parallel operation. It should be observed that if two direct-current generators are running in parallel, slight changes in the relative speeds of the generators amounting to, say, one-half per cent or so, would make very little difference in the amount of power delivered. With alternating-current generators, however, the relation between speeds must be constant.

(4) Irregular Fluctuations in Speed—Difficulty of this nature seldom occurs with steam or hydraulic turbines, but is sometimes experienced with reciprocating engines of insufficient flywheel capacity and is due to a slight irregularity in the angular velocity of the rotating parts. The engines driving the alternators should have the following characteristics:

A. The engine governors should be so constructed that there is no tendency to cause a periodic transfer or surging of the load between one engine and another. This tendency may originate in the angular variation of velocity in different parts of the revolution which is common to all reciprocating engines, or to a sudden variation of load which will affect each governor in a slightly different manner, or to other causes that lead to a non-uniform speed. The engine governors should not be sensitive to such disturbances nor maintain or increase them.

The effect on the engines of a periodic transfer of load, occasioned by hunting between two machines running in parallel is somewhat similar in effect to throwing the load on or off of a single engine at short equal intervals which may be measured by one or several pulsations in the combined turning efforts applied to the engine shaft.

In some extreme conditions the pulsations of load may amount to more than the normal capacity of either engine. With no external load one engine may then alternately drive the other, which will evidently be a more severe condition than if the load were only applied and removed from a single engine.

If under any case of pulsating load the engines do not tend to accentuate the pulsations in turning effort and speed, then a condition favorable to parallel running is attained.

B. Variation of the rotating part of the generator through the revolution at any constant load not exceeding 25 per cent overload should not exceed one-sixtieth of the pitch angle between two consecutive poles from the position it would have if the motion were absolutely uniform at the same mean velocity. The maximum allowable variation, which is the amount the rotating part forges ahead plus the amount which it lags behind the position of uniform rotation, is therefore one-thirtieth of the pitch angle between two poles. Generally this is regulated by the use of a heavy flywheel.

In a 2-pole machine this variation is equivalent to 3 degrees as measured on the circumference of the rotating part; in a 4-pole machine it is 1½ degrees, and in a 6-pole machine 1 degree, or as the number of poles increases the permissible angular variation decreases.

C. The engine should have practically the same characteristics of speed regulation in order that the power delivered to their respective generators may be proportional to the load; that is, the same load on any engine should produce the same percentage drop in its speed. This is most readily obtained in engines in which at full load the speed drops from three to 5 per cent below the no-load speed, as a slight change in adjustment of the governor will have less relative effect than in engines in which the speed drops only one per cent under the same variation of load.

D. The use of governors which are adjustable while the engine is running is recommended. Slight adjustments of speed may then be made which will facilitate synchronizing the alternators or changing the load carried by the engines.

Adjustment of Field Current—When the rheostats of two alternators running in parallel at normal speed are not adjusted to give proper excitation, an idle or cross current will flow between the armatures, which depends only upon the difference in field charges of the machines and which may vary over a wide range, from a minimum of zero when both field charges are normal, to more than full-load current when they differ greatly. The effect of this cross current is to increase the temperature of the armatures and, consequently, to cut down the output of the generators. It is therefore important that the rheostats be so set as to reduce it to a minimum. This cross current is registered on the ammeters of both generators and usually increases both readings. The sum of the ammeter readings will be a minimum when the idle or cross current is zero.

In general, the proper field charge of a machine running in parallel with others is that which it would have if running alone and delivering its load at the same voltage.

In order to determine the proper position of the rheostats it is necessary to make trial adjustments after the alternators are connected in parallel, until that position is found which reduces the sum of the ammeter readings to a minimum.

To illustrate this method let us consider two similar alternators, *A* and *B*, operating in parallel. When the rheostats of both are properly adjusted no cross currents will flow through the armatures and the main ammeters will show equal readings if each machine is receiving the same amount of power from its prime mover. If the rheostat of *A* be partly cut in so as to reduce its field current, a cross current, lagging in *B* and leading in *A*, will flow between the armatures, the effect of which will be to strengthen *A*'s magnetization and weaken *B*'s until they are approximately equal. The resultant electromotive force of the system will thereby be lowered. On the other hand, if the rheostat of *B* be partly cut out so as to increase its field current, a cross current leading in *A* and lagging in *B* will flow between the armatures, strengthening *A*'s magnetization and weakening *B*'s magnetization until they are again equal. The resultant electromotive force of the system will thereby be raised. A cross current of the same character is therefore produced by decreasing one field current or increasing the other, i.e., in both cases it will lead in the first machine and lag in the second machine. The electromotive force of the system will, however, be decreased in one case and increased in the other.

From the above it is obvious that by a combination of changes in the two rheostats, i.e., by cutting one in and the other out at the same time, the strength of the cross current may be varied considerably while the electromotive force of the system remains constant.

For the first trial adjustment cut in *A*'s rheostat several notches and cut out *B*'s the same amount, so as not to vary the electromotive force of the system. If this reduces the sum of the main ammeter readings, continue the adjustment in the same direction until the result is a minimum. After this point is reached a further adjustment of the rheostat in either direction will increase the ammeter readings. If the first adjustment increases the sum of the ammeter readings it is being made in the wrong direction in which case move the rheostats back to the original positions and then cut out *A*'s rheostat and cut in *B*'s. If both adjustments increase the sum of the ammeter readings the original positions of the rheostats are the proper ones.

In making these adjustments of the rheostats it may be found difficult to locate the exact points at which the cross current is a minimum, as it may be possible to move the rheostats over a considerable range when near the correct positions without materially changing the ammeter readings. When the adjustment is carried this far, it is close enough for practical operation.

If the generators are provided with power factor meters, the same result may be obtained by adjusting all these to read the same.

Automatic Voltage Regulator—For details of operation when voltage regulator is used, see instructions with regulator.

To Cut Out a Generator Which is Running in Parallel with Others—(1) Preferably, cut down the driving power until it is just sufficient to run the generator empty. This will reduce the load on the generator.

(2) Adjust the resistance in the field circuit until the armature current is a minimum.

(3) Open the main switch.

It is usually sufficient, however, to simply disconnect the machine from the bus-bars thereby throwing all the load on the remaining machine without having made any previous adjustment of the load or of the field current.

Caution—The field circuit of a generator to be disconnected from the bus-bars must not be opened before the main switch has been opened; for, if the field circuit be opened first, a heavy current will flow between the armatures.

PHASE AND CAPACITY

For a single-phase generator the output in kva. is proportional to the product of the current in amperes and the potential in volts.

For a two-phase generator the total kva. output is equal to the sum of the outputs of the two single-phase circuits, so that if the load be balanced it is equal to twice the output of one phase.

For a three-phase machine with balanced load the total kva. output is equal to the output of one phase multiplied by 1.732.

POWER FACTOR

When any alternating-current and its electromotive force are in the same phase, i.e., rise and fall in strength exactly together, the power in the circuit is the product of the current and the electromotive force. But when the current lags behind the electromotive force, as in the case of a current flowing to an unloaded induction motor or transformer, or when the current is in advance of or leads the electromotive force, as in the case of the current to a condenser, to a second generator, or to a synchronous motor or a rotary converter with high field charge, the power in the circuit is less than the product of the amperes and volts. In cases where the currents lead or lag behind the electromotive force, the **actual power** in the circuit will be equal to a **certain definite per cent** of the power that the circuit would represent were the current and electromotive force in phase. This per cent is called the "power factor" of the circuit. It is the ratio between the true power and the "apparent" power. Its value depends upon the amount the current lags behind or leads the electromotive force.

An incandescent lamp load gives a power factor of 90 per cent to 95 per cent. Fully loaded transformers and induction motors, when running near full load, give high power factors, but unloaded transformers and lightly loaded motors give a low power factor, the average value being 70 per cent. Arc lamps give a power factor varying from 0.7 to 0.8 at full load. As the load is reduced the power factor decreases rapidly and lightly loaded constant-current transformers have an extremely low power factor. Synchronous motors and rotary converters give a power factor dependent on their field current. The power factor is therefore under control of the operator and care should be taken that the field current is correctly adjusted.

REPAIRS

Ordering of Repair Parts—Repair parts of any standard Westinghouse generator may be secured on short notice. To avoid misunderstanding it is advisable to give the serial number of the stationary or of the rotating part of the generator, as the case may be. The former will be found stamped on the generator name plate and the latter on the end of the shaft. When material for coils is ordered, it should also be stated whether or not insulation for the winding is also desired.

Save the shipping notices sent when the apparatus is shipped as they give the number of our shop orders on which the apparatus has been built and this "S.O." number is an excellent means of indentification and materially assists in quickly locating all records regarding the parts.

Rebabbitting Bearings—The old babbitt should first be melted out and a suitable mandrel prepared. Split bearings should be babbitted one-half at a time, and the mandrel should consist of a half-cylinder with shoulders running along its length on which the sides of the bearings may rest so as to form a close fit when the bearing housing is in position for babbitting. Pieces of felt should be placed between the ends to prevent the babbitt from running into the oil well in the spaces back of the bearing shell. Use only the best babbitt metal. The melted babbitt should be poured in the gate until it begins to overflow and a few moments should elapse before it is removed from the mandrel, in order that the bearing may become quite hard. The bearing housing should then be placed in a suitable chuck or dog and the inside turned to the proper bore. The holes for inspecting the working of the oil rings should then be drilled and the oil ring slots melted to the proper depth. The finishing can be done with a file. If the mandrel is a smooth half-cylinder the oil grooves may be shaped out, but the grooves may be cast by properly designing the mandrel.

Repairs to Insulation—If a defect develops in the outside of a field or armature coil it can sometimes be repaired by carefully raising the injured wire or wires and applying fresh insulation. More extensive repairs should not be attempted by the inexperienced or unskilled.

COMPOSITE-WOUND GENERATORS

Some of the smaller types of single-phase generators, built under the older designs are composite wound, i.e., they have a compensating field winding in addition to the separately excited field winding.

Compensating Winding—With rotating armature machines the spokes on the armature serve as the cores for the series transformers, and two transformers are used in order to secure a mechanical balance. With rotating field generators the transformer core is separate from the machine, and but one transformer is used. The current from the secondary of this series transformer is commutated by means of a two-part commutator mounted upon the generator shaft and is supplied to an auxiliary winding upon the field poles. Rotating field single-phase generators were formerly built with composite field winding in sizes up to and including 100 kilowatts. Above this size the single-phase generators were made separately excited, as are all of the polyphase generators.

Commutator—The commutators of composite-wound generators should be kept smooth by the occasional use of No. 00 sandpaper. Lubricant should be applied to high-voltage generator commutators with a cloth attached to the end of a dry stick. If the commutator gets "out of true" it should be turned down. In the case of revolving armature generators this can be done without removing the rotating

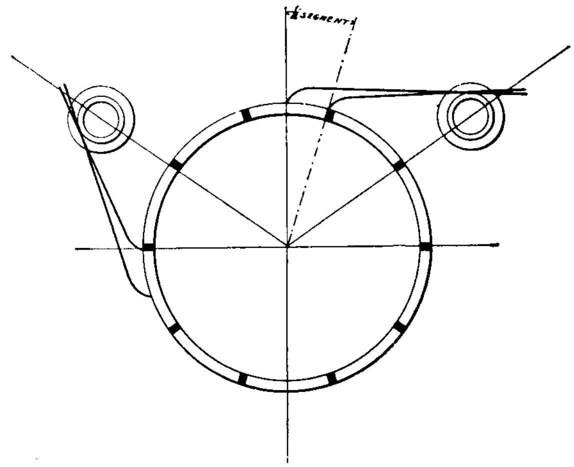


Fig. 15—Correct Position of Brushes on Commutator With 10 Segments or Less

part from the bearings by the use of a special slide rest and by running the engine slowly or the commutator may be taken off the shaft and turned down in a lathe. The commutator may be dismounted by removing the plate at the end of the shaft, releasing the alternating-current connections and taking out the screws in the section between the ring and the commutator, on account of the high voltage between commutator bars the commutator should be short-circuited in cases where the compensating winding is not used.

Brushes of Composite-Wound Generators—The copper brushes used to collect the direct-current from the commutators of alternating-current generators with a compensating winding are beveled and bent into proper shape before being shipped, as indicated in Fig. 12, which shows the correct setting of the brushes on a commutator with ten segments. The number of segments between the brushes depends upon the location of the brushholder rods. The brushes are set one, three, or five segments apart in different machines, and the operation of the commutator will be the same electrically as long as the brushes are an odd number of segments apart, independently of the number of poles.

The brush nearest the field in one holder should be given a lead of about one-half a commutator segment over its companions, while in the other holder the brush at the greatest distance from the field should have an equal lead over the other brushes of its set. In the diagram, the leading brushes touch the commutator at the middle segment, while the trailing brushes are just over the insulation between the segments. The total number of exciting brushes used with a small alternator is four, two to a holder. With larger machines having a compensating field, three brushes per holder are employed.

The brushes should bear upon the commutator with light, but good contact, the leading brush having slightly less pressure than the trailing brushes. Too great a pressure will lead to heating and cutting. It is well to place one set of brushes a little further from the bearing than the other, so that the ridges likely to be formed by one set will be worn away by the brushes of the other set.

It is advisable to set the trailing brushes exactly in position while the generator is at rest, and when once set they should not be changed. Sparkless commutation can be obtained only when the brushes are set in this correct position. The leading brushes may be changed relatively to the trailing brushes while the machine is in operation.

The compounding of a generator may be varied by shifting the brushholder rocker and also, to a slight extent, by changing the spread of the brushes in each holder. Increasing the spread decreases the compounding, and vice versa. When the rocker arm is shifted to give the proper compounding, all brushes may be made to run sparkless by changing their speed. The practical limit of this adjustment is reached when the brushes span one commutator segment, in which case the compound winding is short-circuited, or when all the brushes of each arm are in line in which case the compound winding will be open circuited. If the generator is running on a purely non-inductive load or on a load with a constant power factor, the composite brushes may be permanently set for a given regulation. If, however, the load has a variable power factor, it will be found necessary to adjust the brushes occasionally. The higher the power factor, the less compounding will be necessary for a given regulation, and vice versa. With a widely varying inductive load, it is impossible to adjust the composite brushes so as to obtain absolutely sparkless operation.

Sparking on the commutator may be due to any of the following causes:

(1) Brushes may not be set at point of commutation. A position can always be found where there is no appreciable sparking, and at this point the brushes should be secured.

(2) Brushes may be loose or may not be bearing sufficiently on the commutator.

(3) Brushes may be welded at the end.

(4) Brushes may be spread at the end. They should present a narrow surface to the commutator.

(5) Commutator may be rough; if so, it should be smoothed off.

(6) Commutator may be dirty or oily, or copper dust may have collected on the insulating segments.

(7) Generator may be overloaded.

(8) Compensator circuit may have a loose contact or an open circuit.

Never run a composite-wound alternator with load unless all its brushes are in place, as an unduly electromotive force will be generated in the open circuited composite winding, which may puncture the insulation.

STARTING SYNCHRONOUS MOTORS

Synchronous motors are usually started by applying reduced voltage to the armature winding. The field winding is short circuited during the accelerating period and is excited when the machine reaches its maximum speed as an induction motor. Full voltage is then applied to the terminals.

The exact procedure is as follows:

(1) See that the field switch is in the position to short-circuit the field winding. This is the lower position on standard double-throw field switches.

(2) Close the starting switch handle. This applies reduced voltage, by means of auto transformers, to the armature and should cause the motor to start and accelerate nearly to synchronous speed.

(3) When constant speed has been reached hrow the field switch from the lower to the upper position, thus applying the exciting voltage to the field winding. The best value of field current to apply can usually be found by experiment.

(4) Change the starting switch from the starting to the running position, thus applying full voltage to the motor In some types of starters separate starting and running handles are provided. After the motor has

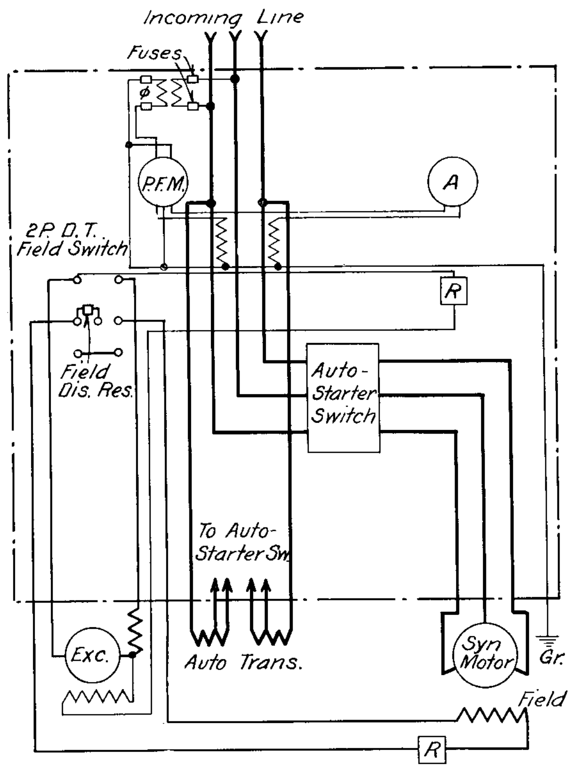


Fig. 16—Diagram of Connections of Self-Starting Synchronous motors—See Fig. 13 for Later and More Complete Diagram

pulled into step but before full voltage has been applied, the field current may be adjusted so as to obtain the minimum disturbance during the throw-over to full voltage. As a general rule, the field current to be used is about that corresponding to normal voltage at no load.

(5) Adjust the field current to the value marked on the motor nameplate. If a motor rheostat is not furnished the adjustment should be made with the exciter field rheostat In case a motor rheostat is furnished and the machine has an individual exciter, the motor rheostat should not be used until the exciter voltage has been lowered to about 75 volts so as to avoid unnecessary rheostat loss.

It is extremely important to wait until the motor has reached its maximum speed as an induction motor before the field is excited. If excitation is applied too soon the machine will usually fail to pull in to step. The field ammeter gives a good indication of the speed and should be watched by the operator. When the machine approaches full speed the needle oscillates slowly, its rate of oscillation decreasing as the speed rises and falls to zero when the motor reaches synchronous speed.

If it is found to be impossible to pull in to step by following the above procedure, the motor should be transferred to full voltage, by closing the running switch, before the field is excited. The field switch should then be changed from the lower to the upper position so as to apply excitation to the field.

For certain applications using slow speed motors, auto transformers are not furnished and the motor is started by applying full line voltage. The starter in this case has only one position, but a push button is furnished which short-circuits the overload relays during starting. The push button is held down until the machine has pulled in to step. This arrangement allows the overload relays to be set for slightly over full-load current and thus give protection during normal operation.

In some cases, a resistance is submitted for the short-circuiting bar on the lower side of the field switch. During starting the field is therefore closed through this resistance instead of being short-circuited. By this means, a variation in the torque characteristic is obtained. No change in the method of starting is required.

Motors having individual exciters which are either direct-connected or belted to the motor and which start under fairly easy conditions may be operated with the field permanently connected across the exciter armature. It is then unnecessary to manipulate the field switch during the starting operation. Under severe starting conditions, this method does not give the best results and it is usually necessary to follow the standard starting procedure outlined above.

Motor Field Current and Power Factor—The field current that is used determines the power factor at which the motor operates. The current required to give the rated power factor with full load output is stamped on the motor nameplate as "Exciting Amps." If the maximum leading Kv-a. is desired at all times the field should be set for this value even though the load is less than rated output.

Motors are built for either 100% power

factor or 80% leading power factor. Those built for 100% power factor furnish a small amount of leading Kv-a. at reduced loads provided the exciting current is kept at the full load value.

Motors rated at 80% power factor furnish leading Kv-a. at all loads. In case there is no necessity for supplying leading Kv-a. to the line it is possible to reduce the exciting current and operate the motor at 100% power factor. This gives slightly lower losses although it reduces the pull out torque of the motor.

Pull Out Torque of Motor—The pull out torque of the motor, or its ability to hold in step when overloaded, is dependent upon the value of the line voltage and the field excitation. Standard 100% power factor motors will pull out at about 175% of rated load while 80% power factor motors will carry loads up to about 225% rated load without falling out of step. These figures are based on the assumption that the line voltage is maintained at its normal value and that full load exciting current is used. By raising the excitation to a higher value the motor can be made to hold in step at greater overloads. Higher exciting current will cause the temperature rise to increase and should not be maintained for long periods. It simply furnishes a means of taking care of short peaks or emergency conditions.

VENTILATION OF TURBINE TYPE ALTERNATORS

Westinghouse steam turbine alternators are of the completely enclosed type, excepting the sizes smaller than 300 kva., 3600 r.p.m. These completely enclosed machines draw their cooling air from special ducts which lead to the outside air, or from the basement in special cases in which cool air can be obtained therefrom, and discharge the air into a special duct or into the engine room. In the smaller sizes above referred to, a semi-enclosed construction is used, air being drawn in at both ends of the machine from the engine room, and discharged again radially through ventilating openings in the frame. In the enclosed machines suitable ducts, through which cool air is supplied from outside the engine room, must be provided by the purchaser. These ducts must be of sufficient size to supply not less than 3.2 cubic feet per minute per kva. rated capacity of the generator, with a pressure drop not exceeding .4 inch water gauge from the outside air to the base of the generator. This requires that the ducts be of sufficient size and be free from sharp or right-angle bends. Special precautions should be taken that the warm air from the machine does not escape into the intake passages.

The outline drawing furnished for each turbo-unit usually indicates the minimum area permissible for air ducts; but, in case of doubt, an outline or sketch showing size and arrangement of the proposed duct should be submitted to the factory for suggestion.

The air is drawn through the ducts by means of a fan, mounted on the end of the rotor, which also forces the air through the laminations and armature winding.

It is advisable to remove the armature end bells at intervals and give the machine a thorough inspection and cleaning. Care should be exercised that dust or oil is not allowed to accumulate either on the armature winding or in the armature vent ducts.

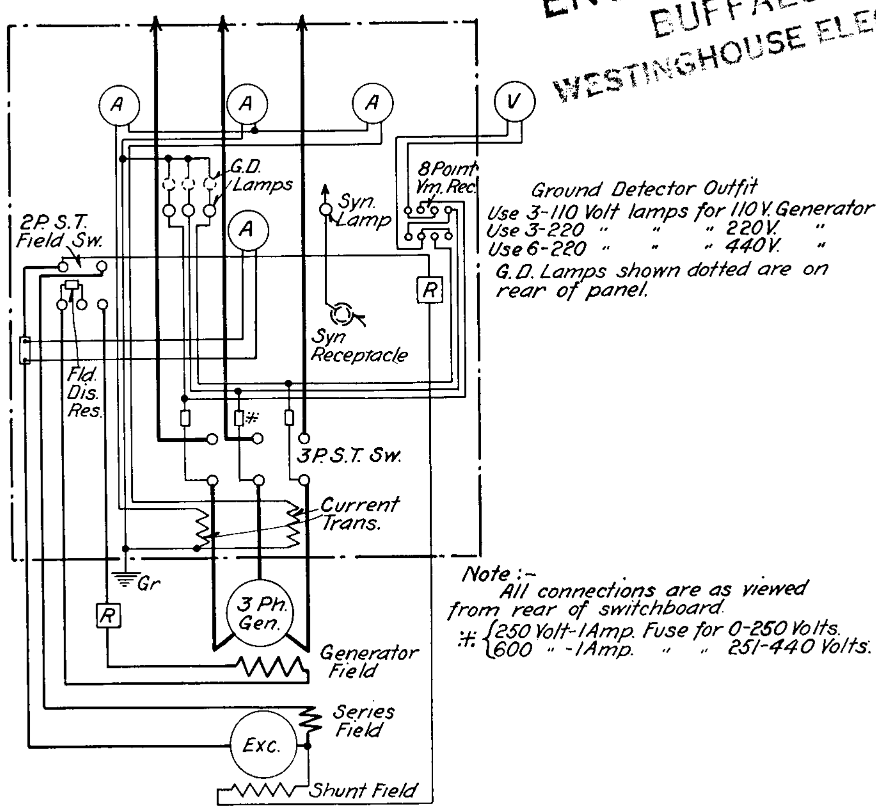


Fig. 17—Diagram of Connections—Three-Phase Generator Type LA2 Switchboard Single-Throw System, 500 Volts or Less

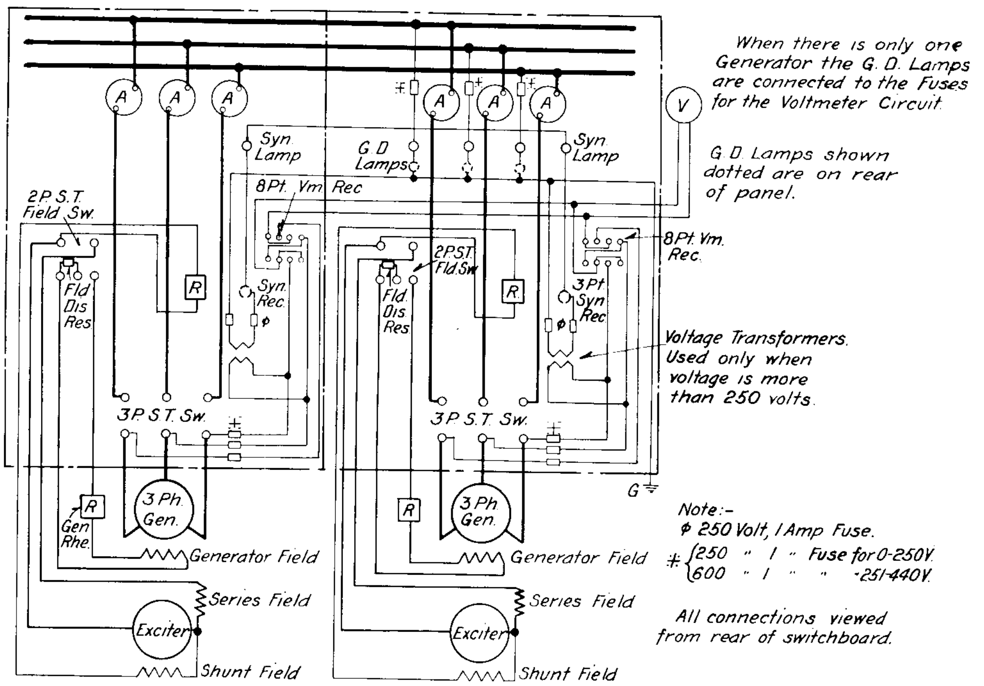


Fig. 18—Diagram of Connections—Two Three-Phase Generators in Parallel Type JA Switchboard, Single-Throw System, 500 Volts or Less

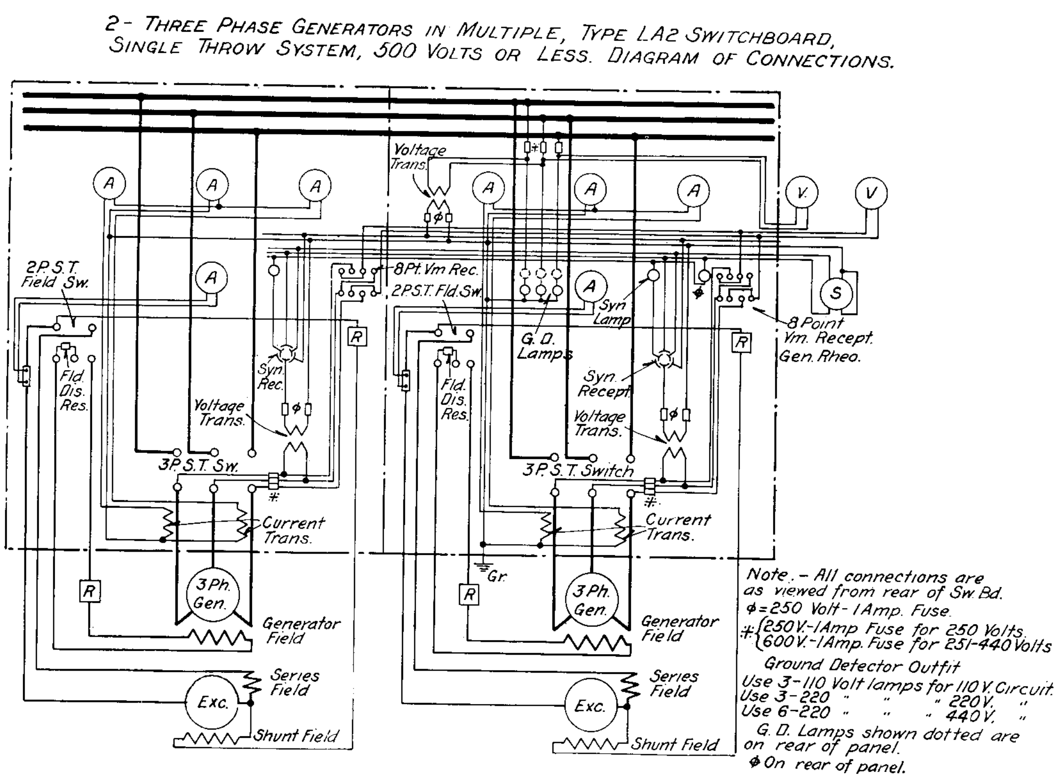
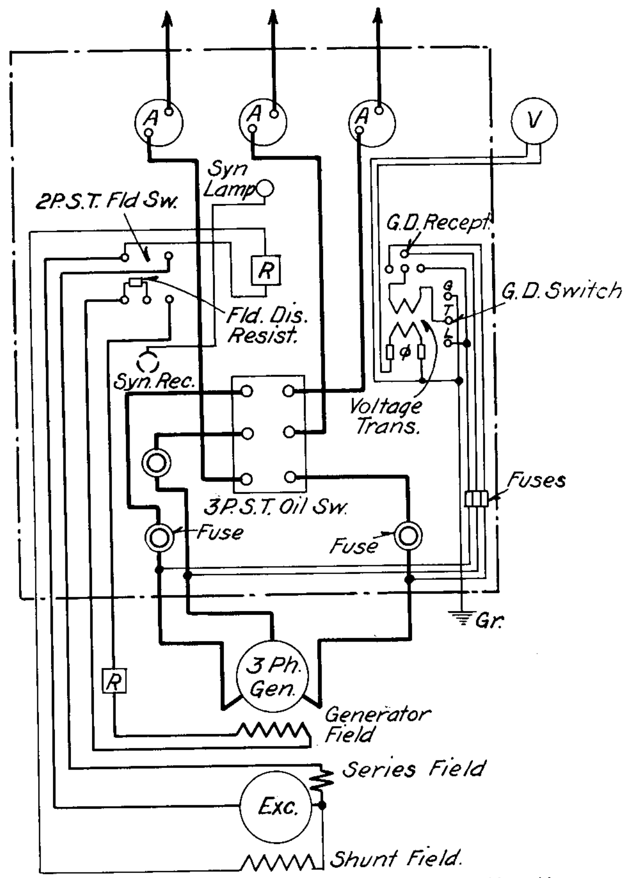
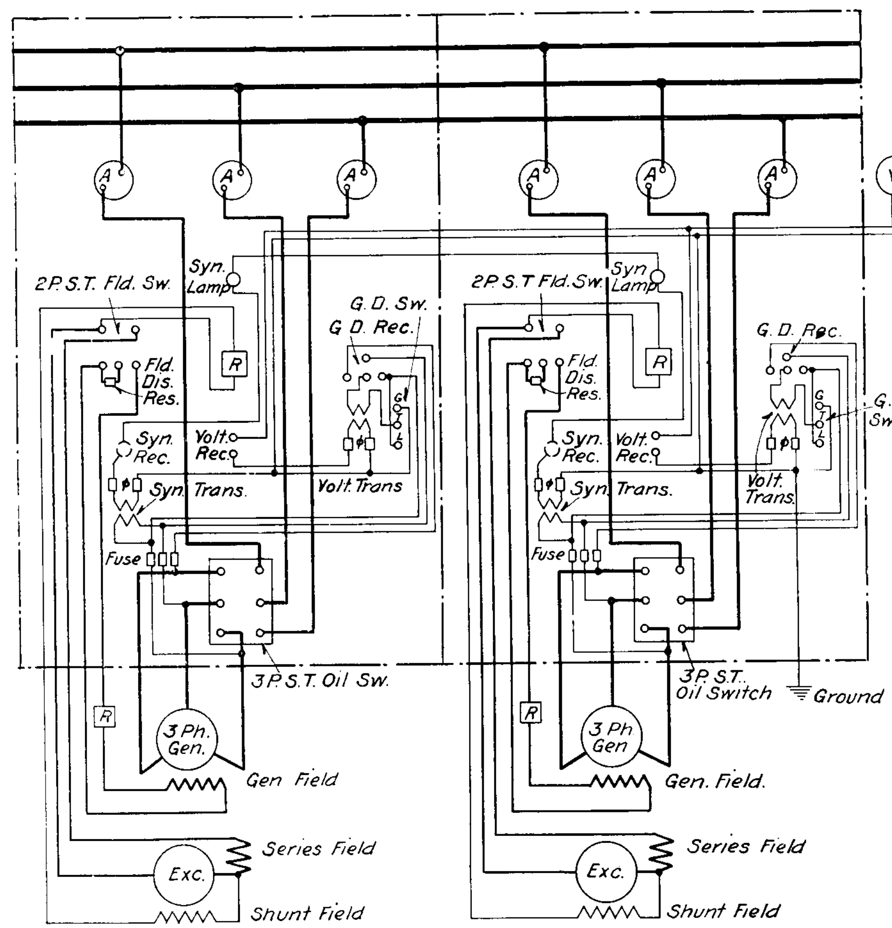


Fig. 19—Diagram of Connections—Two Three-Phase Generators in Parallel Type LA2 Switchboard, Single-Throw System, 500 Volts or Less



Note:- When voltage exceeds 2500 volts, the ammeters are used in connection with current transformers
All connections are as viewed from rear of Sw. Bd.
φ250 Volt-1 Amp. Fuse.

Fig. 20—Diagram of Connections—Three-Phase Generator—Type JB Switchboard—Single-Throw System, 3300 Volts or Less



Note:- All connections viewed from rear of switchboard
φ=250 Volt-1 Amp. Fuse.

Fig. 21—Diagram of Connections—Two Three-Phase Generators in Parallel Type JB Switchboard, Single-Throw System, 2200 Volts or Less

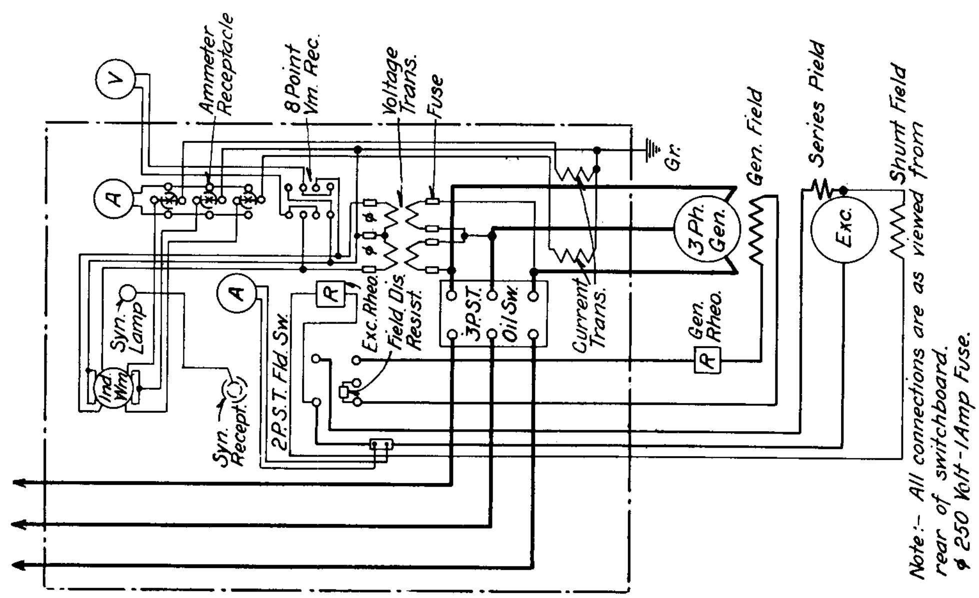


Fig. 22—Diagram of Connections—Three-Phase Generator, Type EB Switchboard—Single-Throw System 6600 Volts or Less

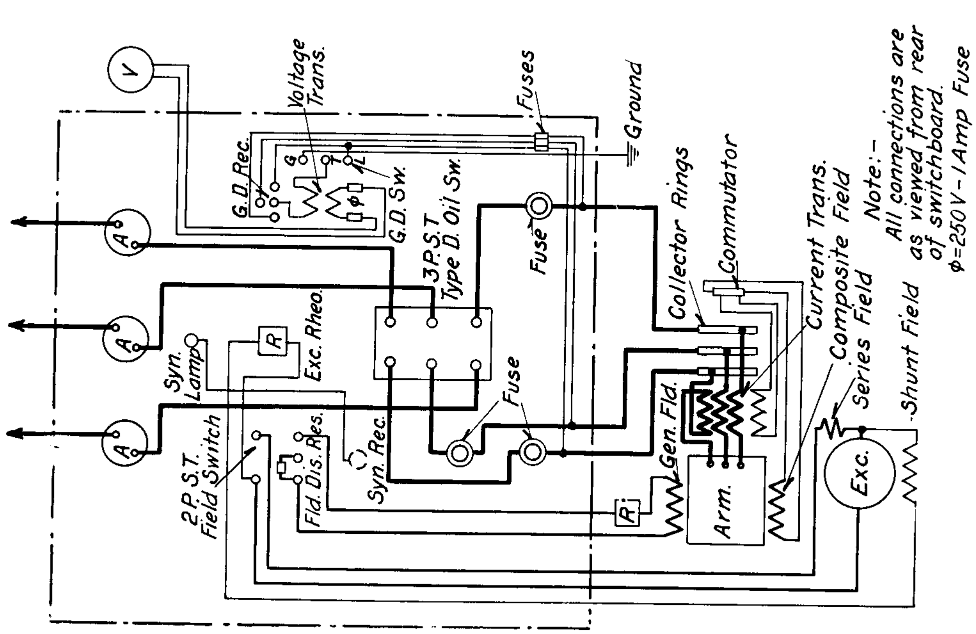
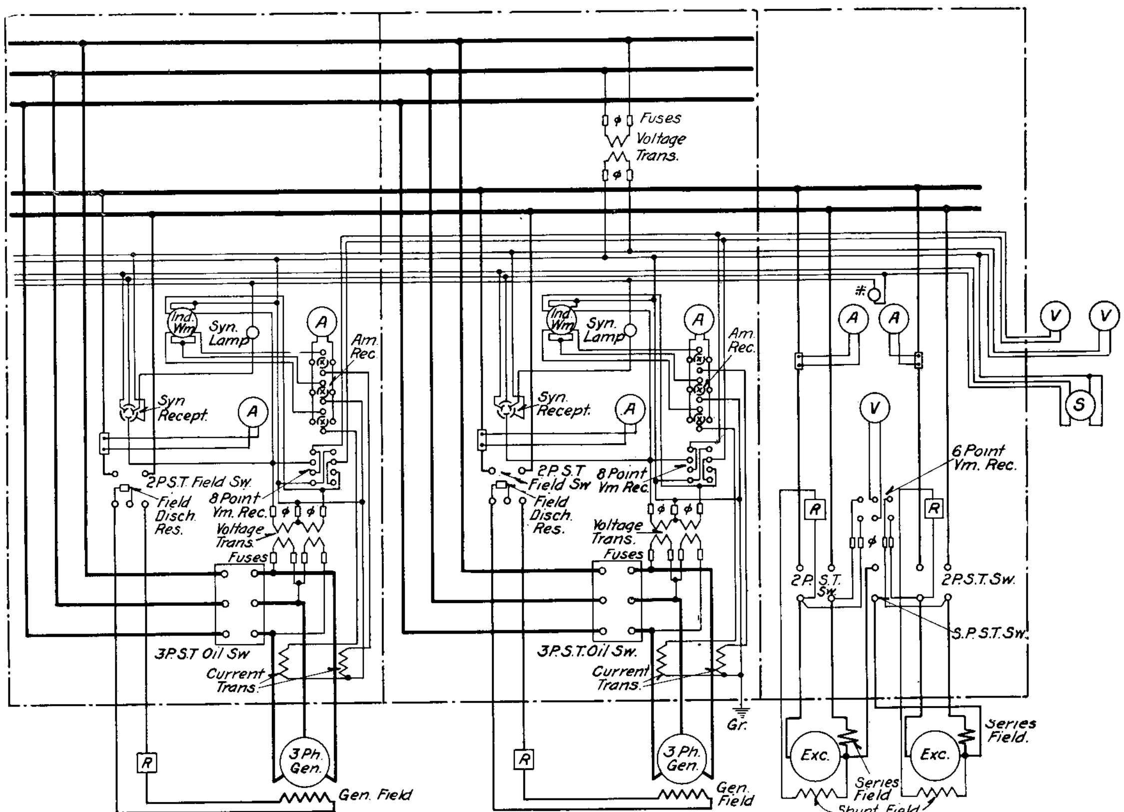


Fig. 23—Diagram of Connections—Three-Phase Composite-Wound Generator—Type JB Switchboard—Single-Throw System 2200 Volts



Note:- All connections are as viewed from rear of switchboard. ϕ 250 Volt -1 Amp. Fuse. # Lamp on rear of panel.

Fig. 24—Diagram of Connections—Two Three-Phase Generators in Parallel Type EB Switchboard, Single-Throw System, 6600 Volts or Less

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