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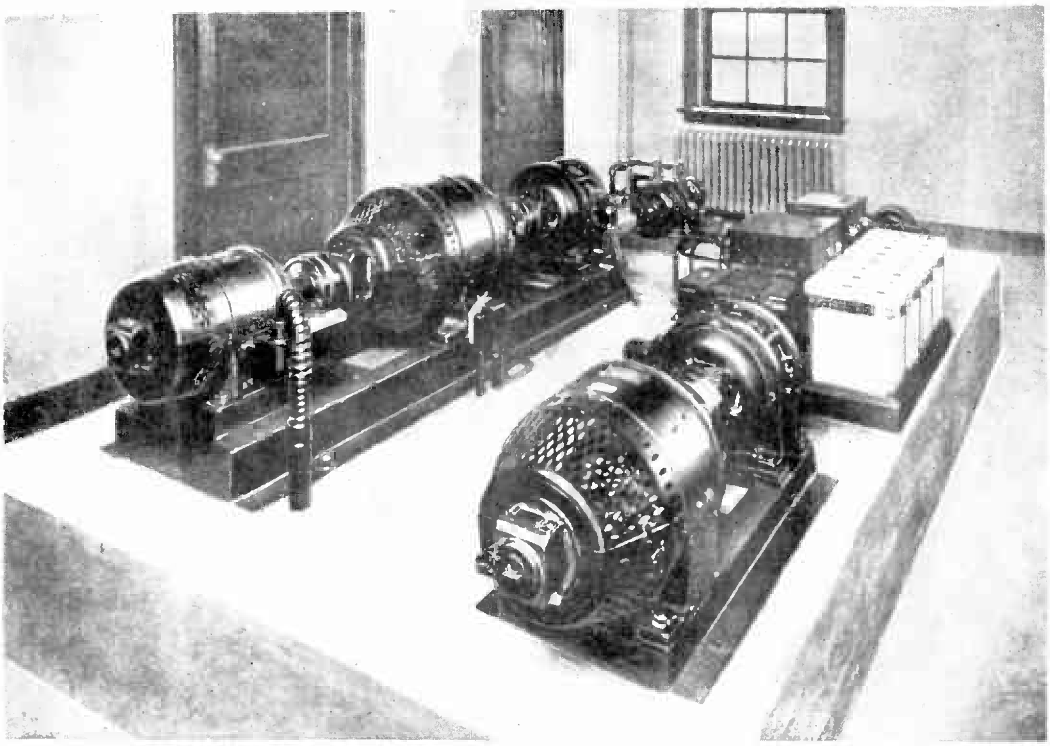
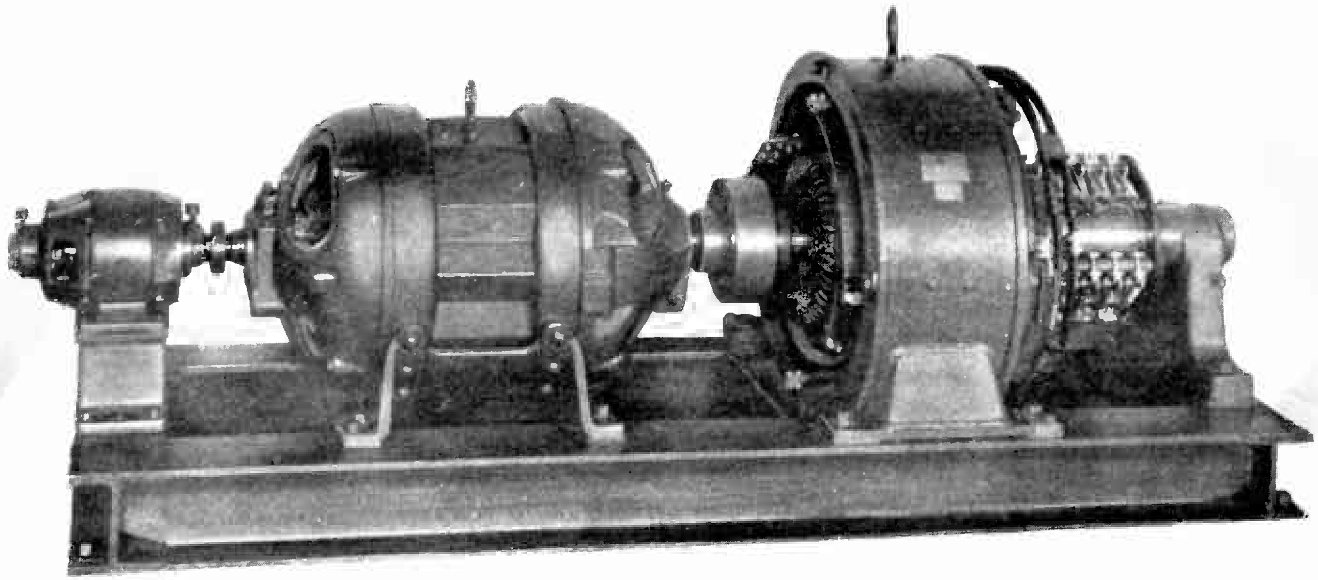


Typical Broadcast Station Power Room

D. C. GENERATORS

VOL.10,No.9

Dewey Classification R100



Filament Motor Generator Set
The unit is capable of furnishing 600 amperes at 35 volts. Exciter is shown at left

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D.C. GENERATORS

The theory of the electric generator and the electric motor are very closely related and the construction of both is practically the same.

The action, however, of the generator is opposite to that of the motor. The generator, or dynamo, as it is sometimes called, converts mechanical energy into electrical energy while, the motor converts electrical energy into mechanical energy.

Electrical energy is taken from a generator when it is driven by an electrical motor or by other means such as a steam or gas engine, or by a water turnbine.

The dynamo can be used either as a generator or motor. The term used to designate a machine depends upon whether it is to be used as a motor or as a generator. In shop practice this method of having one machine which can be either used as a motor or generator is employed to some extent.

HISTORY OF THE GENERATOR

We have to look backward a good many years to find when the first generator was used. In 1821 Michael Faraday, an English scientist, found that he could produce rotation of a magnetic needle when it was brought near a conductor carrying an electric current. He did this while experimenting and applying the discoveries of Oersted in electromagnetism. In 1831 Oersted's great discovery of electromagnetic induction was made and, from that date, you might say the electric generator was born, for it was on this principle that the dynamo was founded. Since then many men have contributed to this discovery and it has taken years of constant study and application to bring the generator to its present-day perfection.

THE PRINCIPLE

Generator:—From the name many people think the dynamo generates electricity. To entertain this idea, however, is wrong. A dynamo can no more generate electricity than a water-pump can generate water. The water is there; the pump merely forces it out of the well. Electricity is already there, and the dynamo only generates a pressure which moves the electric current through a wire.

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In your earlier lessons you spent some time with electromagnetic induction, learning how an E.M.F. was induced in a wire when it moved through a magnetic field. You were then acquiring knowledge which will now enable you to understand the principle of the generator.

If you make a loop of wire and bring the ends out to two "collector" rings as shown in Figure 1, and place this loop in a magnetic field, and so arrange the loop that it may be rotated in this magnetic field, you will have an experimental device suitable to illustrate the principle of a simple generator.

If this loop is now revolved so that the lines of force between the two magnets are cut, an E.M.F. will be induced in the loop and current will flow through the loop "AA" and "BB". The current which is being forced around this loop by the induced E.M.F. will

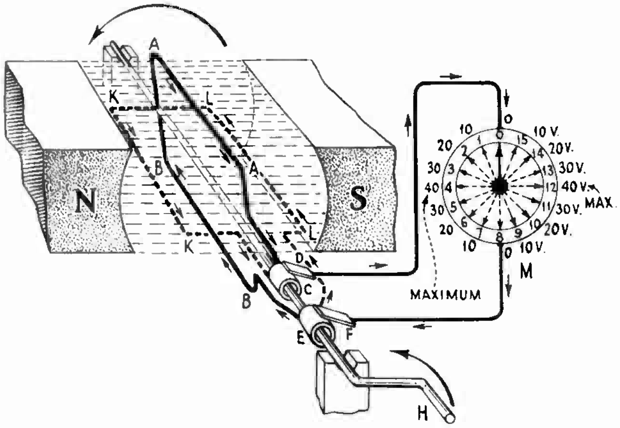


Fig.1-Diagram illustrating the operating principle of a simple generator

flow to the collector ring "C", to the brush "D", and through the meter "M" to brush "F", to collector ring "E" and return to side "BB" of the loop. The current has caused the meter needle to move so we know that current flows in the loop.

If the loop is turned from the position as shown in the diagram by the handle "H" to the left, the side "A.A." of the loop will begin to move through and cut the lines of force at an angle.

As the side "AA" moves in the direction shown by the large arrows the induced E.M.F. will cause current to flow through the loop as shown by the small arrows on the loop. More lines of force are cut as it moves toward the dotted lines "KK", which represents the loop at the point where it cuts the greatest number of lines of force or at right angles, and when it reaches this position the maximum E.M.F. is induced and the greatest current flow naturally results.

As the loop moves out of this point of greatest field strength toward position "BB" less and less E.M.F. is induced as the loop gradually approaches the point "BB"; at point "BB" the loop moves parallel to the magnetic field and no lines of force are cut consequently no E.M.F. results.

While side "AA" has been moving down, side "BB" has been moving up, and the induced E.M.F. in side "AA" is in the opposite direction to that in side "BB".

We said that when the top of the loop moved downward from point "AA" to point "KK" E.M.F. was induced in that side of the loop which increased in strength until at point "KK" the maximum E.M.F. was reached. As the loop continued beyond position "KK", the induced E.M.F. gradually became less until, at point "BB",it dropped to zero.

The induced E.M.F. gradually increased from zero at point "AA", to a certain point and then decreased again to zero.

Suppose we study Figure 2 and see what we can get out of that picture to help us understand this E.M.F., or voltage rise and fall.

Here we have something that looks like a cart wheel; at the center is a hub and from this hub are radiating lines or arrows which point at figures around the rim of the wheel. Start at the hub now and

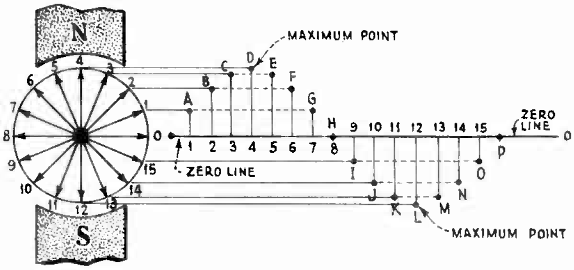


Fig.2-Diagram illustrating voltage increase and decrease in a simple generator

study the arrow which points to zero. Just opposite zero you will see a line which we will call the zero line; this zero line extends, we will say, for 15 inches, and the numbers, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, will then be at intervals of an inch.

The arrow above and to the left of arrow 0 points to 1, the next arrow above and to the left of arrow 1 points to 2, and so on around the rim of the circle until we return to arrow zero.

We are going to let the arrow which points to zero represent the position of side "AA" of the loop in Figure 1.

We want you to follow this very carefully for you are going to construct a curve which is the method used by all electrical men to show how electric current moves in an A.C. circuit. It is important for you to know this for you are going to see many similar curves before you finish this work and we want you to understand how the curve is obtained.

The loop will be rotated through the magnetic field. Before moving the loop, however, let us look over the special meter we have arranged at M, Figure 1, to indicate the amount of the induced voltage as it increases and decreases in the loop during its journey through the lines of force.

On the inner circle of the meter you find numerals 0 to 15; these correspond to the movement of the loop. On the outer circle 10v (10 volts) 20v, 30v, 40v appear and, following the circle around, 40v, 30v, 20v, 10v, 0 volts appear. Now let us start the loop and, if it were possible to observe the individual readings as the loop is turned, the following results would be noted.

The loop moves from point zero, the neutral or zero position, to point 1, and has cut lines of force for a distance of one inch. Glancing quickly at the meter M, Figure 1, we find that the voltage has increased from zero volts to 10 volts. At this position, or point "A", Figure 2, place a dot. The loop moves on, and our next point of observation is at point 2. Again reading the meter we find the voltage has increased to 20 volts, so at point "B", Figure 2, another dot is placed. As the loop revolves, and arrives at point 3, Figure 2, we take our reading of 30 volts, and another dot is placed at point "C", (Note that the voltage is increasing as the loop approaches the point where it is cutting more lines of force at right angles). At point 4, another reading is taken and we find the meter reads 40 volts. So we place a dot at "D".

The arrow pointing to Number 4, Figure 2 represents the loop in position "KK", of Figure 1.

As the loop moves downward from point "KK" in Figure 2 to point "BB", the resulting positions are shown in Figure 2 by numbers 5, 6, 7, 8. We find that at point 5 the voltage has dropped to 30 volts, or 10 volts less than at point 4, and a dot is placed at point "E". Our next reading is at 6. The meter reads 20 volts and a dot is placed at "F"; at point seven the voltage has dropped to 10 volts and a dot is placed at "G" and, as point 8 is reached, the meter shows zero volts and a dot is placed at "H".

The foregoing is called one alternation; the voltage at the start was zero and it gradually increased until the maximum of 40 volts was reached when it receded again to zero value.

As the portion of the loop "BB", Figure 1, continues it begins to travel upward through the lines of force inducing an E.M.F. opposite in polarity to that induced on its downward travel. Naturally the current will change its direction of flow. We will show you how to plot this by using Figure 2.

The loop is now moving from position "BB" towards "LL", Figure 1 and as it leaves point 8, Figure 2, and reaches point 9 we find that the meter reads 10 volts. Following out our line to point "I" another dot is placed. (Note that the voltage is increasing again, but in the opposite direction). Point 10 is now reached in the upward travel of the loop as it comes under the influence of the "S" pole of the magnet, and our meter reads 20 volts; another dot is placed at "J". when 11 is reached the meter reads 30 volts and another dot is placed at "K"; point 12 is next with a meter reading of 40 volts or the maximum voltage of the alternation.

The voltage now begins to drop and, as points 13, 14 and 15 are passed, we read a voltage of 30, 20 and 10 volts respectively, with dots placed at "L", "M", "N" and "O". Finally when the loop reaches zero, the starting point, the voltage has dropped to zero and, with a final dot at "P", a cycle of values has been completed, i.e., two alternations.

Now starting with the dot at zero draw a continuous line through A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, to P and you will have a curved line as shown in Figure 3. Draw a straight zero line beginning at zero through "H" to "P" and a true sine curve is the result, shown in Figure 4.

From this study it is seen as the portion of the loop leaves the point "AA", Figure 1, it moves downward and cuts the lines of force under the influence of the magnet "N", (north polarity) and the

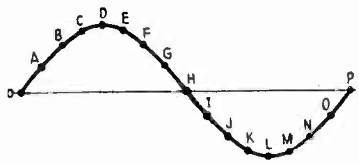


Fig.3-Voltage curve diagram

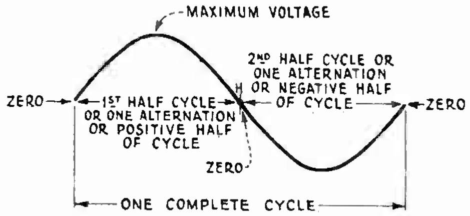


Fig.4-A true sine curve

induced E.M.F. is in one direction while the loop leaving the position "BB" is cutting the lines of force under the magnet "S" (south polarity) upwards, inducing an E.M.F. in the opposite direction.

To lead this induced alternating current out of the loop two collector rings "C" and "E" are mounted on the shaft, insulated from each other, to which are connected the ends of the loop and on which rest the brushes "D" and "F" as shown in Figure 1. Leads connect the brushes to the meter and, as just explained to you, as the loop

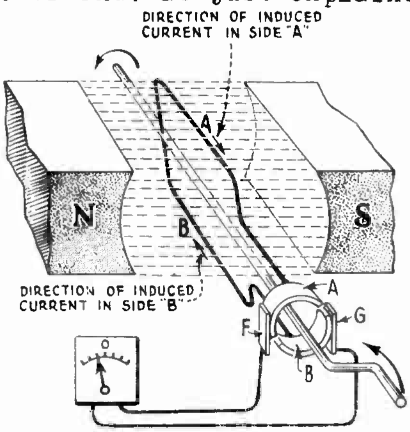


Fig.5-Diagram of a simple direct current generator

revolves, the needle of the meter indicates the rise and fall of induced current at the various parts of the revolution or cycle. These results may be plotted similar to the curve you have just made.

Alternating current is used to a great extent, and we will discuss that in another lesson. However, at this time we are dealing with direct current dynamos, therefore it is necessary to provide some means for changing alternating current to a direct current, or a current which flows in the external circuit in one direction.

This may be done by removing the collector rings, shown in Figure 1, from the shaft and substituting a commutator about which you have alreadv studied. This is shown in Figure 5. Here only one loop is used. Therefore only two segments are needed. The metallic ring is split into two segments A and B and, where they are split insulation is placed, which is flush with the outside face of the segment. The ends of the coil are soldered to each segment as shown in Figure 5. The loop "A" and "B", as shown in the diagram is parallel with the magnetic field and this is the position where no E.M.F. is induced as indicated by the small meter. (Also note the brushes short circuit both segments; that is the neutral or no voltage position).

Now by turning the handle in Figure 5 so the loop revolves counter-clockwise, or to the left, side "A" of the loop begins to cut the magnetic field of the magnet under the "N" pole inducing an E.M.F.

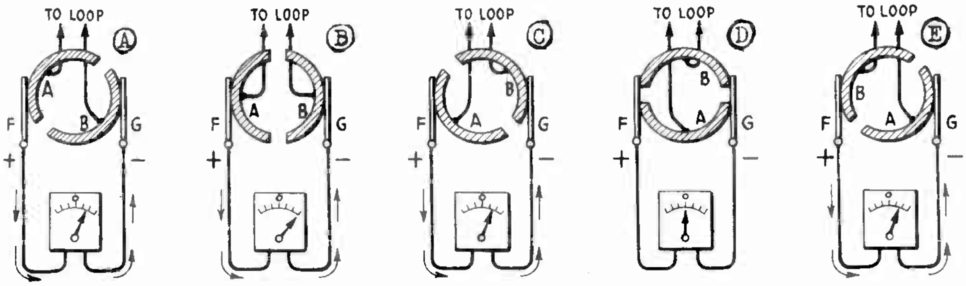


Fig.6-Diagrams of various commutator positions in the simple direct current generator

which causes an induced current to flow in this half of the loop as shown by the arrow. The commutator segments which are secured to the shaft have moved into the position as shown in Figure 6A, and the induced current is flowing to segment "A" and out brush "F" through the meter to brush "G", into segment "B", and to the "B" side of the loop.

At the same time, the "B" half of the loop has moved upward, as shown by the arrow in Figure 5, cutting the magnetic field of magnet "S", inducing an E.M.F. in this half of the coil causing an induced current to flow through "B" half of the loop, as shown by the arrow, which is opposite in direction to that of side "A".

The coil has now taken the same position as shown in Figure 7 by the arrows 2 and 6.

As the loop rotates it reaches the position 3 and 7, Figure 7, with the commutator as shown in Figure 6B. Position 4 and 8, Figure 7, is the next position of the loop with the commutator in position Figure 6C.

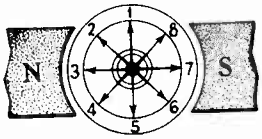


Fig.7-Loop positions

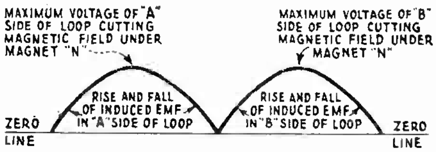


Fig.8-A direct current sine wave

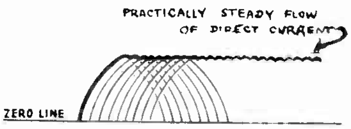


Fig.9-A pulsating direct current graph

At position 1 and 5, Figure 7, the "A" side of the loop in Figure 5 is at position 5, while "B" side is holding the position that "A" formerly held at the start. The loop is again in the neutral plane, at which point no E.M.F. is induced in the loop.

The "A" side of the loop and the "A" segment of the commutator could be considered positive at this point, and the "B" side of the loop and "B" segment of the commutator negative. The commutator is shown short circuited at 6D and in this position the loop is parallel to the magnetic field at which time no current flows.

Continue to rotate the loop (Figure 5), however, and side "B" and segment "B" now becomes positive, while side "A" and segment "A" are negative, Figure 6E, and the same cycle of events take place over and over again as the loop continues to rotate.

Thus, you can readily see that at each half revolution the current changes direction in the loop as it comes under the influence of the different magnetic poles. The commutator, however, keeps the current flowing in the external, or meter circuit, always in the same direction, thus supplying direct current to the external circuit.

Thus, with only one coil on the armature and using a commutator the current would rise and fall, but would not reverse its direction. This condition is shown in the curve Figure 8, and is called a pulsating direct current. This condition is not desirable, because if a lamp is connected in the circuit instead of the meter the lamp would appear dim at first then bright at the point of maximum voltage, then grow dim again and at each half revolution of the loop the lamp would go out. In order to eliminate this undesirable feature of alternate increase and decrease of the E.M.F. a great number of loops are used with a correspondingly great number of segments.

With more loops revolving in the magnetic field the pulsating current becomes as shown in Figure 9, giving a greater number of pulsations per second of time.

The loops are so arranged that each coil replaces the preceding loop coming into the magnetic field so rapidly that the E.M.F. is practically constant. One coil no sooner passes out of the maximum voltage point than another is arriving at the same point.

However, even with a large number of armature coils, and a correspondingly large number of segments, these slight fluctuations of the current will still be present. Such fluctuations of the current are known as "commutation ripples," but are so small in value that, as far as ordinary circumstances are concerned, they are of no importance.

If we revolve the armature through the magnetic field and the armature coils are self supporting, the reluctance which the air gap between the poles offers to this magnetic field will materially reduce its strength.

All armature coils are wound on a soft iron laminated armature core. This iron core practically fills the space between the magnetic field poles, reducing the reluctance offered to the magnetic field and therefore a greater number of lines of force may be cut. The distance between the revolving armature core and the field magnet pieces is usually 1/64 of an inch.

FIELD POLES

The field magnets of motors and generators are generally large electromagnets. The core in most cases is either cast iron, wrought iron or soft steel. In some types of small motors the frame and pole pieces are permanent magnets and these require no field winding.

In the larger types that we are dealing with the field magnets are electro-magnets and are made up separately and bolted to the frame of the motor or generator. The field pole is machined carefully to fit closely to the frame, because a tight joint reduces magnetic leakage. The field pole, "A" in Figure 10, is soft iron cast into shape, and then machined as shown. Holes are drilled for the holding bolts and provisions made to countersink the heads of the holding bolts into the shoe of the pole piece.

The form wound field coils are next prepared as shown in B. In series wound motors the field coils consist of heavy insulated wire. As each turn is wound on the form, shellac is applied. Upon completion of the winding as shown at "B", Figure 10, it is wrapped with cotton tape shellacked again and baked. The completed winding is then ready for the pole piece, which is removed from the frame, and the field coil is slipped over the pole piece fitting close up to the shoe of the core, as shown at "C", Figure 10. The completed field coil is then placed inside the generator frame, bolted into place and the terminal of each coil connected as shown at "D", Figure 10. The placing of the pole pieces as to polarity, together with the path of

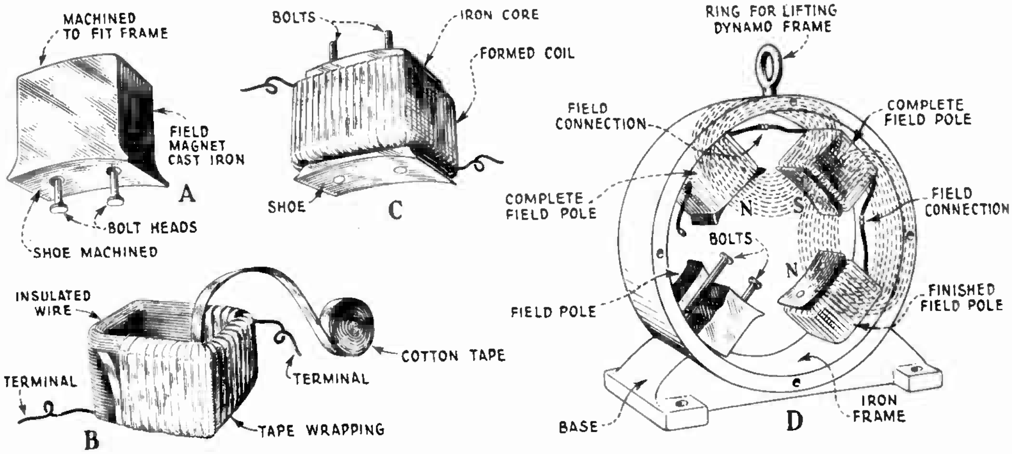


Fig.10-Details of the field magnets in a direct current generator

the magnetic field through the frame, is also shown at "D", Figure 10. This figure shows a four pole generator. Bipolar (two pole generators) are also used.

The field coils are connected in different ways according to the design of the machine. In most commercial direct current generators the fields are self excited; that is, they are energized from the current generated in the armature. In alternating current generators the field is generally excited separately by a small D.C. generator connected directly to the armature shaft of the alternator, or from the D.C. supply mains.

The soft iron used in the field magnet retains a small amount of magnetism, called residual magnetism, after the generator is shut down. On starting the generator this residual field makes it possible for the armature coils, as they cut this weak field, to generate an induced E.M.F. thereby starting an induced current. As soon as current begins to flow in the armature it strengthens the field winding, gradually building up the magnetic field strength until it becomes normal.

There are times when this residual magnetism fails; that is, the pole pieces lose their magnetism to such an extent that the E.M.F. will not build up. In this case it is necessary to separately excite the field magnet winding by connecting several dry cells in series with the field coils to produce a field strong enough for the armature to develop an E.M.F. As soon as the E.M.F. starts to build up the dry cells are disconnected and with the field circuit restored, the machine will operate normally.

Let us observe some of the ways the generator field coils are connected with the armature, which designates the type of D.C. generator. To make this as easy as possible we will use three drawings; all three slightly different in appearance but, nevertheless, the circuits are the same.

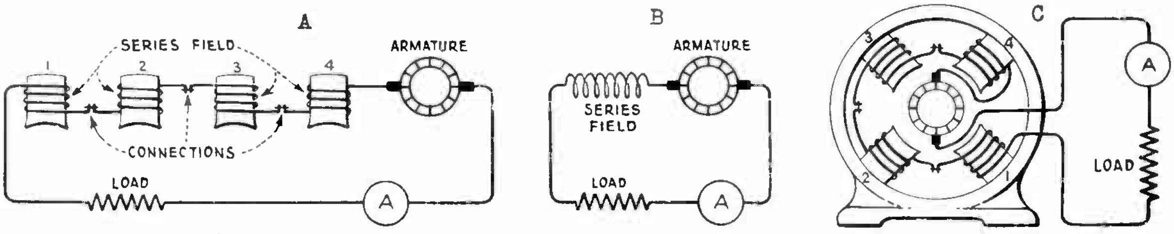


Fig.11-Diagrams illustrating series wound field coil connections

Figures 11A, 11B, and 11C show the connections for a series generator in which the field coils are connected in series with the armature; all the current passing through the armature windings must pass through the field windings as well.

Suppose first we lay four field magnets out in a row as shown in Figure 11A. Connect them all in series and then connect No. 4 to the armature brush; the other field winding terminal, No. 1, goes to the load and meter. The other armature terminal goes to the meter. This is a series connection. Figure 11B is a schematic drawing of the same thing, while in Figure 11C we have placed the coils and armature in a frame. By tracing the circuits you will find "A" and "B" the same.

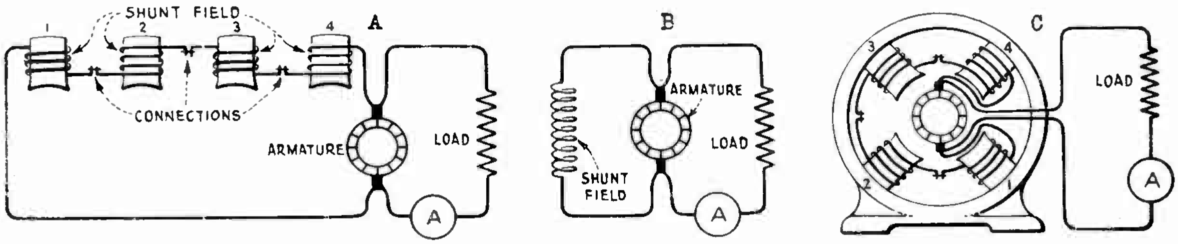


Fig.12-Diagrams illustrating shunt wound field coil connections

The shunt type of D.C. generator is shown in Figures 12A, 12B and 12C. Notice that the field coils are wound in series with each other and connected across, or in parallel with, the armature coils and NOT IN SERIES. The coils are wound with a large number of turns of fine wire as only a small portion of the armature current flows through the field. Figure 12A shows the field coils in a row. Figure 12B is the schematic drawing, and in Figure 12C the field coils are shown placed in the generator frame.

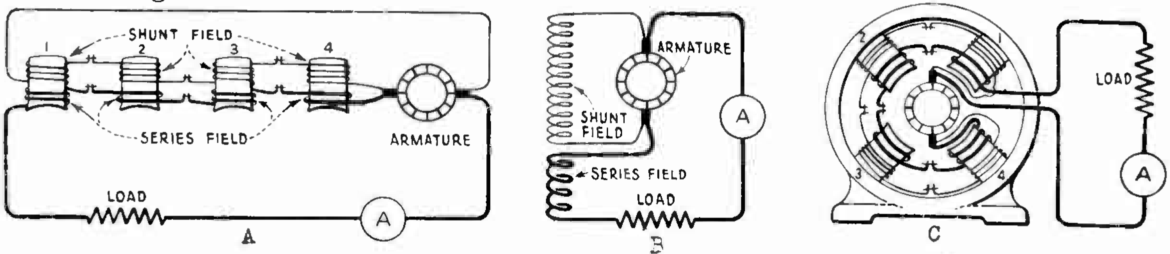
The compound wound generator is a combination of both the series and shunt generators, having both a series and shunt field. The characteristics of both the series and shunt machines are thus combined in one machine and much better regulation of the voltage is secured under all conditions of varying loads.

The series winding is connected in series with the armature and the load as shown in Figure 13A,B and C, while the shunt field is connected in parallel or in shunt, with the armature.

The action of the windings is as follows: When a load is thrown on the generator the shunt field is weakened and at this point the series field helps out by strengthening the shunt field thereby automatically maintaining a constant voltage under a varying load.

The current in the compound wound windings must flow through both the series and shunt windings in the same direction in order that the resultant field will be strengthened.

The electromotive force or voltage generated depends upon the following factors:



A B C

Fig.13-Diagrams illustrating compound wound field coil connections

1st. The number of loops or conductors on the armature revolving in the magnetic field.

2nd. The strength of the magnetic field or lines of force.

3rd. The rate at which the armature carrying the loops or conductors move through this magnetic field.

It is necessary therefore that these factors be given careful consideration to obtain maximum voltage from a generator.

For a detailed explanation of the commutator refer to Figure 9 and the text associated therewith on D.C. motors. Both the assembly and discussion of the commutator is presented.

The brushes used in nearly all types of generators are made of carbon. The hardness and softness depends upon the copper segments of the commutator. A soft copper segment requires a soft carbon brush while on hard copper a hard brush can be used. The degree of hardness of the copper is not changed intentionally; this variation occurs during manufacture and different grades of carbon brushes are made to meet this condition. The size of the brushes primarily depends upon the amount of current being taken from the armature of the generator. If the current is high in value then brushes large enough to easily pass such current must be used. Conversely, if the current is low in value then proportionately smaller brushes are used.

The device holding the brush in the proper place and bearing on the commutator is called the brush holder, a diagram and explanation of which is shown in Figure 14.

This brush holding device is secured to a brush frame from which it is insulated, fitted with a handle, and so arranged as to allow the brushes to be shifted around the commutator. This is called the rocker arm and allows the brushes to be moved at times in order to compensate for distortion of the magnetic field. This is explained under the subject of "armature reaction".

ARMATURE REACTION

Armature reaction is caused by the effect of the magnetic field about the rapidly revolving iron armature and its coils upon the main magnetic field set up by the field coils and this reaction distorts or draws the main magnetic field out of its natural position. The neutral point is thereby changed and the brushes must be shifted to compensate for this reaction. This change in the setting of the brushes is shown in Figure 15.

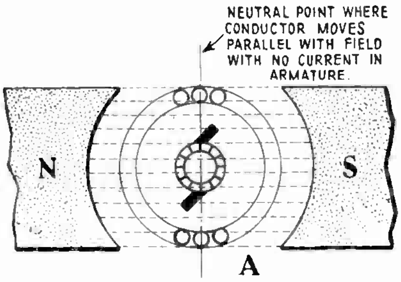


Fig.14-Diagram showing the use of the brush holder

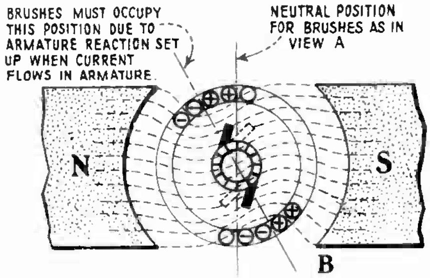


Fig.15-Diagram illustrating required adjustment of brushes to compensate for armature reaction

By referring to the cycle of events in the loop as shown in Figure 6 and the neutral point mentioned there, armature reaction may be more readily understood with the following explanation. The neutral point or plane, you remember, is that point where the armature loop or coil moves parallel with the magnetic lines of force and is the point of zero voltage or where no induction occurs. The current changes direction in the loop at either side of zero position. Armature reaction changes this neutral point, or point of commutation, as it is most generally termed.

Suppose that an armature revolves in a magnetic field with the external circuit open or not connected to the brushes on the commutator. The main field will in this instance remain normal, that is, the lines of force will extend from N to S, or from north to south magnetic poles as shown by the dotted lines in Figure 14. When a load is thrown on the generator the circuit through the armature coil is closed and reaction between the field proper and the field of the armature results. This reaction between the armature field and the magnetic field of the pole pieces causes the normal neutral plane to shift, and it is readily seen that the coils, which are passing the point where the neutral plane formerly existed without any load on the armature, are not moving parallel with the magnetic field but are cutting the lines of force at an angle; see Figure 15. Therefore the brushes must be moved to that new position of the neutral point which results from such distortion of the magnetic field, for at this new point the coils on the armature will be travelling parallel with the distorted magnetic field. The proper adjustment for the brushes is at the "point of commutation". The brushes must be shifted on both generators and motors.

FIELD CHARACTERISTICS

Each of the aforementioned types of field winding produces a generator with different output voltage characteristics.

A voltage characteristic curve for a series wound machine is shown in Figure 16. It will be seen that the voltage output increases with load until a certain load current is reached; at this point the voltage starts to fall off rather rapidly. The reason for this is that the field windings have reached a condition of magnetic saturation so that further increase in current gives no further increase in excitation. In addition the armature reaction is increasing causing a reduction in effective excitation flux. The armature IR drop is also increasing.

The output voltage characteristics of a shunt wound machine are shown in Figure 17. Here it will be noticed that a comparatively high value of E.M.F. is produced even at no load, but the curve falls off gradually until a certain value of current is reached at which point it falls off abruptly. This curve can be kept relatively flat by the use of a rheostat in series with the field which could be used to adjust the amount of excitation for each change in load.

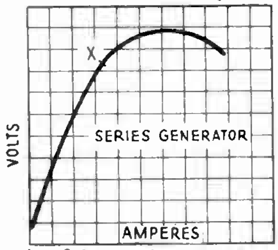


Fig.16-Series wound generator voltage curve

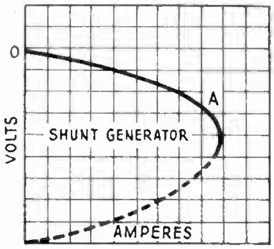


Fig.17-Shunt wound generator voltage curve

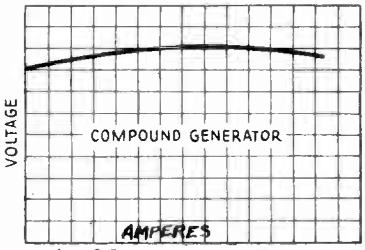


Fig.18-Compound wound generator voltage curve

As the load through the armature increases there is an increase in armature reaction as well as an increase in IR drop through the armature. This causes considerable voltage drop at the armature terminals or brushes reducing the impressed voltage on the field resulting in rather a large decrease in field excitation. The sharp dip in the curve shows where this excessive excitation drop takes place.

By reference to the two curves it will be seen that Figure 16 shows a rising voltage characteristic and Figure 17 a falling voltage characteristic. The compound wound generator which is a combination of the two windings produces a voltage characteristic which is a combination of those shown in Figures 16 and 17. This characteristic is shown in Figure 18 and it will be readily seen that this approaches the ideal characteristic where the generator is to be operated under varying load conditions.

TYPES OF COMPOUNDING

There are in use three types of compound windings:

1. Flat compound; a winding so designed as to keep the voltage constant under wide variations in load.
2. Over-compound; a winding designed to permit the voltage to increase slightly as the load increases.
3. Under-compound; voltage drops slightly as load increases.

THE EFFICIENCY OF D.C. GENERATORS varies from 77% in the smaller sizes to as high as 94% in the larger size units. Efficiency of a generator may be stated as an equation as follows:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

or since it is sometimes difficult to measure the input to a generator the equation may be stated:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Output} + \text{Losses}}$$

It is desirable at times to express the voltage regulation of a d.c. generator in terms of percentage. This is stated as a formula as follows:

$$\text{Voltage regulation} = \frac{\text{No load voltage} - \text{full load voltage}}{\text{Full load voltage}}$$

The losses in a generator are three in number, namely:

1. Iron losses (hysteresis and eddy currents)
2. Copper losses (I^2R in armature and field)
3. Mechanical losses (bearing friction and windage)

The watts lost in the iron of the armature are caused by hysteresis and eddy currents.

Hysteresis losses it will be remembered are losses incurred by the reversal of the molecules of iron each time the direction of magnetic flux is reversed. The amplitude of these losses in a generator are dependent upon the number of reversals made per second of the magnetism in the armature core, the amount of iron in the core, the quality of the iron and the density of the magnetism in the iron. Generally the softer the iron the lower the losses due to hysteresis.

Whenever a conductor cuts lines of force an E.M.F. is induced in it. This applies to the armature core as it does to the conductors. These currents tend to flow from one end of the armature to the other under one magnetic pole and return under an opposite magnetic pole. These currents require power to establish and maintain them. This power is expended in the form of heat which tends to heat up the armature and might reach a point where it would prove damaging to the insulation. However by making up the armature of laminations of thin discs and insulating each disc from its neighbor this trouble can be largely eliminated.

The copper losses are the watts lost in the excitation of the field and the losses due to resistance of the armature coils.

The mechanical losses are made up of the friction of the brushes rubbing on the commutator, friction of the bearings and the friction of the air which is called windage.

POSSIBLE TROUBLES

Generators should be watched carefully to correct troubles which may appear unimportant at first but which may later become serious. The most important possible troubles follow:

The bearings of a generator and motor should be kept in good condition; the oil should not be allowed to become gummy. The oil rings should be watched at all times to see that they are carrying oil to the shaft and bearing.

Figure 19 illustrates a bearing and oil rings. "A" is the bearings with the oil rings in the slots fitted loosely on the shaft. The dotted lines show the shaft which carries the rings; as the shaft turns in the bearing the oil rings which rest on the revolving shaft also turn, picking up oil as they rotate and thus splashing the oil onto the shaft. "B" shows the pillow block, the lower half containing the oil well (the rings are shown in dotted lines) the upper half of which is held in place by bolts and is called the "housing" which covers the bearing.

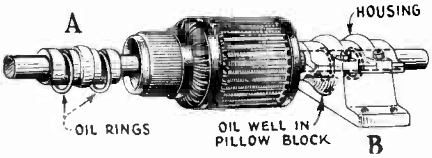


Fig.19-Armature bearings and oil rings

The brushes must be given special care. They should fit into the brush holders in such a manner as to prevent "chattering" and still be free to move up and down.

The spring holding the brushes in contact against the commutator should be examined and adjusted for proper tension to avoid scoring of the commutator by the brush.

Keep the brushes and brush holder free from dust and see that the face of the brush resting on the commutator is fitted properly to the commutator in order that the brush bears evenly at all points against the segments. Should it become necessary to refit the brush to the commutator do so as shown in Figure 20. Lift the brush and place a piece of double O (OO) sand paper with the smooth side against the commutator. Allow the brush to drop back against the rough or sanded part of the paper, then allow the sand paper to follow the curvature of the commutator and with a back and forth movement the sand paper will cut away the carbon brush, insuring a close fit. The tension of the spring will keep the brush against the sand paper while you are moving it back and forth. This is the only abrasive that should be used for the purpose. DO NOT USE EMERY PAPER. The machine should be so left that it cannot be accidently started during the process of fitting the brushes.

Keep all abrasives, especially those of a metallic nature, away from the commutator and bearings; emery paper will cause short circuits between the segments of the commutator and will cut the bearings if allowed to come in contact with them.

Sparking at the brushes can be caused by high spots on the commutator which should be remedied. Rough or pitted commutators should be turned down on a lathe. Excessive loads at times cannot be avoided, but after such instances the brushes and commutator should be examined and cleaned and given as good care as possible. The mica insulation between the copper segments is often higher than the segments themselves; the mica should then be cut down on a lathe. If the brushes are out of the neutral plane, i.e., point of commutation, they may be correctly adjusted by shifting the

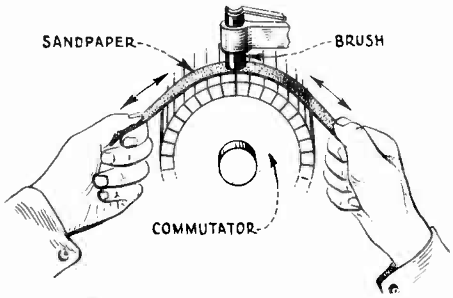


Fig.20-Illustrating method of cleaning and shaping brushes

rocker arm. If a brush becomes wedged in its holder it should be removed and be given a thorough cleaning.

An armature coil which is partially short circuited will cause sparking; this must be located and repaired.

The commutator may at times become extremely hot due to excessive current being drawn from the generator. There is, in this case, only one remedy; reduce the load on the generator to normal.

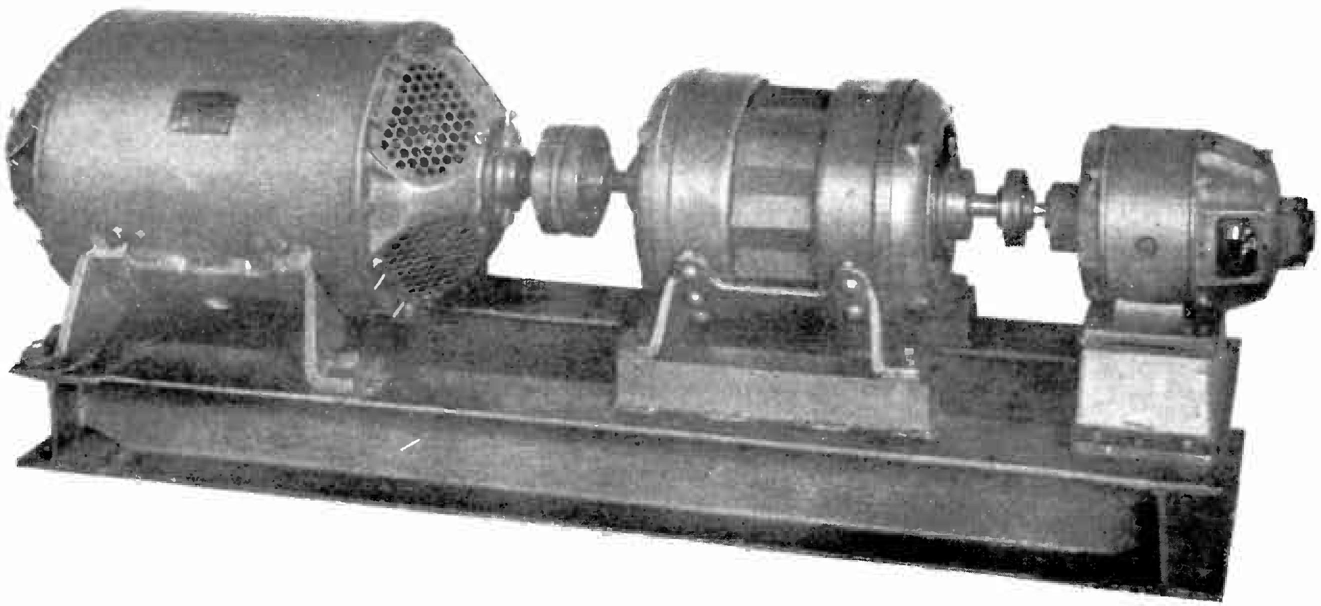
The armature loops or conductor terminals may become loose in the segments; this raises the resistance of the contact and produces heat.

At times metallic particles become lodged between the segments of the commutator due to gummy oil which has been splashed there from the bearings. The particles come under the brushes and being deposited between the segments, they cause sparking. The commutator and brushes should be cleaned, using clean gasoline on the commutator and polishing with a piece of heavy canvas.

A burned out, or shorted, or grounded armature coil will cause sparking. Tests for locating such trouble will be given you later, together with tests for locating short circuits, grounds and broken connections.

EXAMINATION QUESTIONS

1. Is there any major difference between an electrical motor and an electrical generator?
2. What is the purpose of an electric generator?
3. What grade of emery paper should be used to clean a commutator?
4. What is the purpose of field poles?
5. What is meant by the term "residual magnetism"?
6. Draw a diagram of a shunt generator.
7. (a) What are brushes used for? (b) What care should they receive?
8. Are the bearings of a generator considered important?
9. Suppose the field poles lose their residual magnetism, how would you proceed to overcome this difficulty in order that the generator might be used?
10. What is the purpose of collector rings?



Bias Motor Generator Set
Unit consists of driving induction motor, exciter and two generators on one frame. Each generator has individual fields and controls

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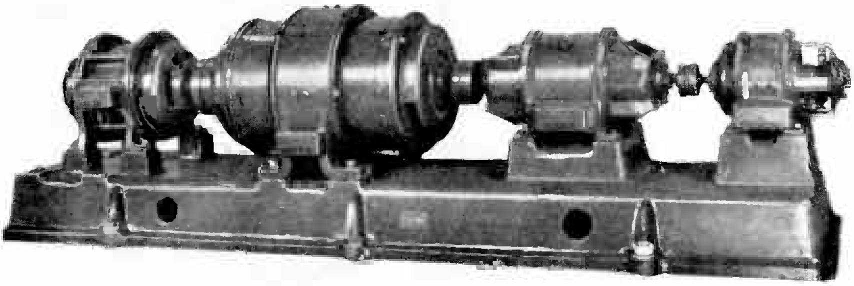

Motor generator set consisting of driving motor, high voltage generator, grid bias generator and exciting generator

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