In concluding their article the authors point out that if the automatic development means anything at all it will now be possible to develop a large number of small, low-head plants and to tie them in on a high-tension system, leaving their operation entirely to the float switch and voltage relays. If there is voltage on all three phases of the high-tension line and water for the turbines, they will start up and go onto the line without wrecking themselves or disturbing the operation of the remainder of the system. In these days of scarcity of coal and of labor, together with high prices for these, the utilization of our water power is of national importance. With the elimination of the excessive cost of labor for small plant operation, many water-power sites can be made paying investments.

Keeping Direct-Current Apparatus from Flashing

High Speed Circuit Breakers and Arc Barriers Have Been Proved Effective in Limiting the Effects of Short-Circuits

THE latest practice in protecting d.c. equipment from flashing was described in a paper by J. J. Linebaugh and J. L. Burnham, both of the General Electric Company, Schenectady, N. Y. The subject is of particular importance at this time on account of the flashing problems incident to the automatic substation and to high-voltage heavy traction. As the authors point out, the problem of protection from flashing has for many years confronted engineers who build and operate d.c. machines. Some form of barrier has been the most common protection suggested, but most attempts to apply this plan have been unsuccessful. It was realized, also, that the means for preventing flashing at the commutator and brushes of d.c. machines must operate to remove the cause very quickly. In this paper a special form of barrier which gives the required protection, and two forms of high-speed circuit breakers were described.

A flash at the commutator starts from excessive sparking, produced by the breaking of current in the coils short-circuited by the brush as each segment of the commutator passes from under the brush. The spark or arc tends to hold, due to the inductive character of the coil, and if the arc is of sufficient volume the vapor produced thereby forms a low-resistance path between segments and from brush to brush or to frame. The value of load that causes flashing when applied suddenly, *i. e.*, short-circuit, is a function of the time required to throw it off. The quicker the circuit is opened the higher the value of current that will not cause arcing.

With the ordinary circuit breaker which begins to open at about one-quarter of a second there is a certain maximum load which cannot be exceeded for each commutating machine without causing flashing. If feeders have a sufficient resistance to limit the short-circuit current to this critical value, flashing will occur only on the rare occasion of a short-circuit in a feeder itself. It has been the standard practice of nearly all manufacturers to recommend the tapping of feeders, especially railway feeders, at a sufficient distance from the substation to insure enough resistance in the circuit to limit current in case of short-circuit near the station.

With special high-speed circuit-opening devices, operating at about 0.005 second, the more sensitive machines, such as 60-cycle synchronous converters for railway voltages, may be short-circuited without flashing over even though the maximum current is of higher value than would cause flashing with suddenly applied load in ordinary circuit-breaker operation.

After considerable experimentation the engineers of the General Electric Company decided to concentrate their energies on the design of a circuit breaker using the principle of a latch, a heavy spring and a series tripping coil. The problem was to obtain very quick tripping, rapid acceleration of contact and a sufficient number of ampere-turns in the magnetic blow-out to insure rapid breaking of the arc. A very special latch with a light tripping movement was designed somewhat similar to the hair trigger on a rifle, so that about 0.001 in. movement of the plunger would trip the breaker.

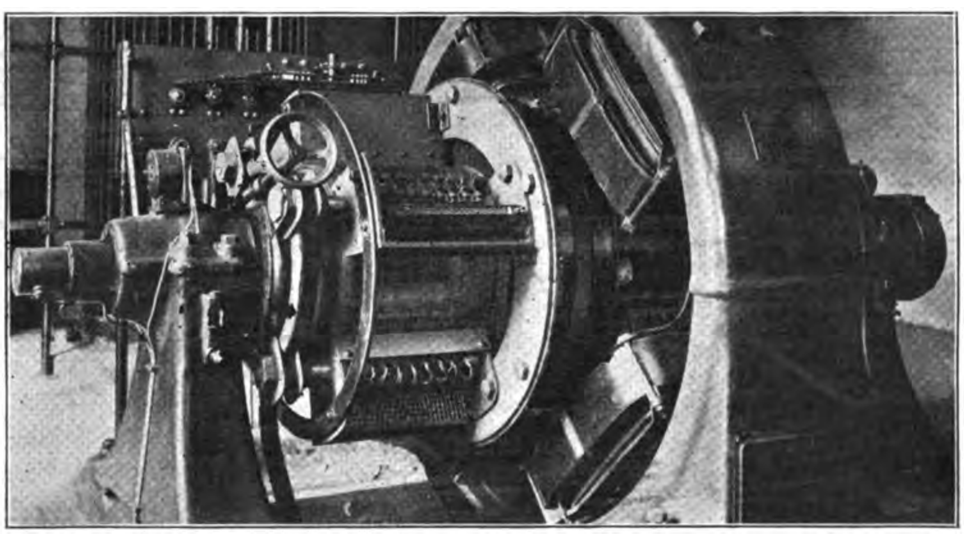

FIG. 1—FLASH BARRIER INSTALLED ON 2000-KW., 3000-VOLT, SYNCHRONOUS MOTOR-GENERATOR SET USED IN CONNECTION WITH HIGH-SPEED CIRCUIT BREAKERS. FIG. 2—500-KW., 25-CYCLE, 600-VOLT SYNCHRONOUS CONVERTER EQUIPPED WITH COMMERCIAL FORM OF FLASH BARRIER INSTALLED IN AUTOMATIC SUBSTATION

A breaker of this type was tested exhaustively in connection with a 2000-kw., 3000-volt d.c. sychronous motor-generator set built for the Chicago, Milwaukee & St. Paul electrification, and some have been in service in the substations of this railroad since early in 1917.

Later another type of high-speed breaker has been developed and forms part of the more recent equipment being furnished to the St. Paul. This consists essentially of a contactor having a laminated structure with electric holding coil and series bucking coil so that it opens when the load current reaches a value sufficient to offset the ampere-turns of the holding coil.

Arc Barriers Are Necessary Also

In connection with the tests described it was found that even with the very high speed obtained it was not possible completely to protect the machines from flashing on the most severe short-circuits, and barriers were designed and installed to supplement the circuit break-

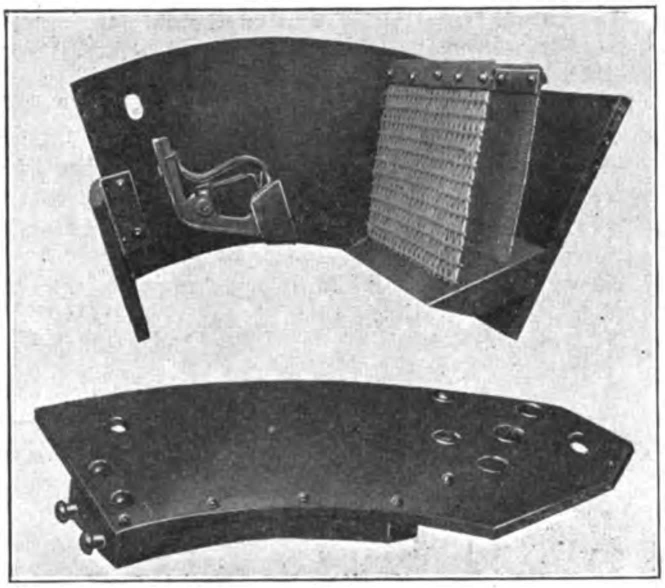

FIG. 3—FLASH BARRIER WITH FRONT REMOVED TO SHOW LOCATION AND CONSTRUCTION OF ARC SCOOP AND WIRE MESH ARC COOLERS

ers. Barriers of the type shown in Fig. 1 were installed to delay the time of flashover so that the breaker could give complete protection.

Further experimenting resulted in the general arrangement of a successful barrier as shown in Fig. 2. Here a close-fitting box of fireproof insulating material surrounds each set of brushes and is located so as to give a small clearance between the box and the commutator. On the side of the box toward which the commutator rotates after leaving the brush is fastened a V-shaped "scoop" (see Fig. 3) of fireproof insulating material, preferably having good heat conductivity. This points toward the brush and has a small running clearance from the commutator. Radially above the scoop about 1 in. apart are two metal screens, one coarse and one fine mesh, through which the arc is successively forced and cooled.

The scoop runs very close to the commutator with narrow edge and small clearance and picks up the arc from the commutator and deflects it into the arc coolers which, from their construction, allow free passage of all gases generated by the arc. The cooling and condensing of the arc reduces the gas pressure so that shields at the end of the commutator, installed to prevent the arc from being thrown from the end of the commutator and communicated to the pillar block and frame, are permissible.

Direct-current machines for use in automatic substations are being equipped with these barriers and short concerted tests at the substations have been taken, indicating that they will take care of any short-circuit experienced in actual service. These barriers are in operation and short-circuit tests were taken on a 500-kw., 600-volt, 25-cycle synchronous converter of the Des Moines Electric Railway; a 500-kw., 600-volt, 60-cycle synchronous converter of the Columbus Electric Railway & Light Company, Columbus, Ohio, and a 500-kw., 30-cycle, 1200-volt synchronous converter at Montieth Junction, Mich., and other installations are now in service.

The investigations and tests indicate that if any commutating machine is equipped with barriers and the last high-speed circuit breaker described, complete protection will be given against external short-circuits of all kinds so that interruptions to service will not be of any greater duration than necessary for closing the circuit breaker as in ordinary overload operation.

Discussion on Anti-Flashing Apparatus

The paper of Messrs. Linebaugh and Burnham brought out some interesting discussion. One speaker referred to methods developed by the Interborough Rapid Transit Company to prevent flashover. In one case a condenser was connected in series with the trip magnet so that the latter would be actuated when there was an instantaneous drop in voltage. He emphasized the disadvantages of a high-speed breaker stating that it is easier to use a choke coil with the trip coil shunted across it. With this arrangement the switch will open when there is an impulse voltage impressed.

Another speaker commended the method described by the authors as logical in supplementing existing apparatus. He mentioned another method of attacking the problem, consisting of the short-circuiting of the windings of the machine through collector rings to reduce the voltage below the flashover point and at the same time to reduce the field flux. (See ELECTRIC RAILWAY JOURNAL, May 4, 1918, page 858.) Attention was also directed to the disadvantages of barriers in that the commutator and brushes are rendered inaccessible thereby.

Large Diameter Trolley Wheels Give Good Results

The Oakland, Antioch & Eastern Railway is reported to be enjoying continued success with various makes of 10-in. trolley wheels originated by this company and described in an article by F. A. Miller in the ELECTRIC RAILWAY JOURNAL of Aug. 14, 1916, page 278. With a 6-in. wheel previously used, the limit of life was frequently as low as 90 miles with a trolley pole tension of 35 to 40 lb. With the 10-in. wheels it was found that the tension could be reduced to from 25 to 30 lb. and the life of these wheels with this reduced tension was increased to 6000 miles and more. Wheel dewirements and pole troubles were also greatly decreased.