Symposium on Railway Substations

Four Papers Read at the Meeting of the American Institute of Electrical Engineers in Pittsburgh Summarize the Status of Converter Protection, Automatic Control and Related Developments

A FEATURE of the 385th meeting at the American Institute of Electrical Engineers, held in Pittsburgh, Pa., on March 12, was a group of papers by substation design experts on subjects which are uppermost in the minds of electrical engineers today. Abstracts of these are given below, and a summary of the discussion following will be printed in a later issue of this paper.

Short-Circuit Protection for Direct Current Substations*

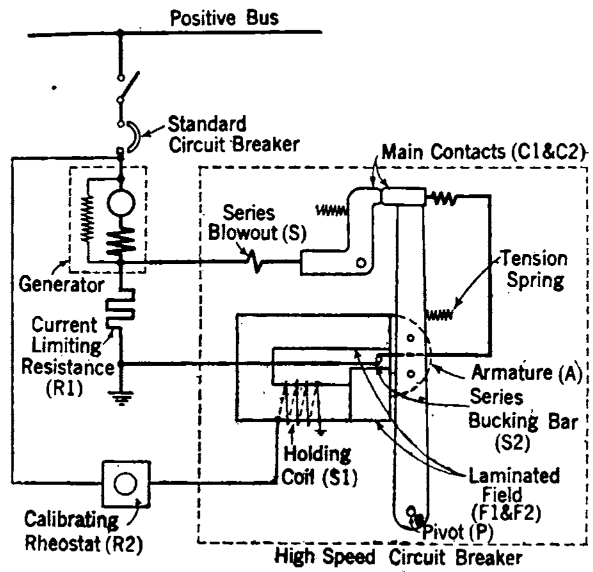
A Résumé of Development of Flash Barriers and High-Speed Circuit Breakers With Special Reference to the St. Paul Electrification

BY J. J. LINEBAUGH
Engineer Railway & Traction Engineering Department, General Electric Company, Schenectady, N. Y.

THE investigation of means to prevent flashing of direct current machinery and the development of suitable equipment have been continued since the presentation of the paper on "Protection from Flashing for Direct-Current Apparatus" by J. L. Burnham and the writer, read at the Atlantic City convention of the Institute in 1918.†

The study covered in that paper indicated that a special form of flash barrier without coolers and a new form of high-speed circuit breaker with current limiting resistance had proved the most promising development, and that tests showed that the two types of protection provided complete protection from a "dead" short circuit caused by short circuiting the terminals of a machine without external resistance. These two types of protection have been further perfected and are now in regular commercial use. They are used either separately or together, and in many instances are considered standard railway practice.

Thirteen of the improved breakers were installed by the Chicago, Milwaukee & St. Paul Railroad, as part of the electrification of its Pacific Coast and Cascade Mountain divisions.

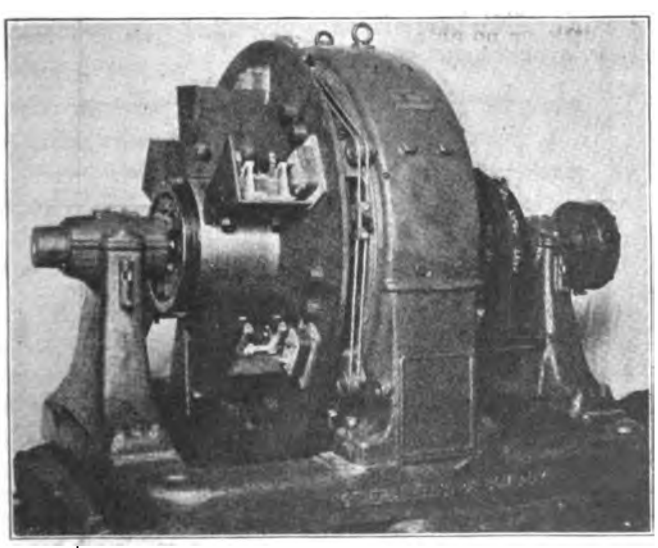


CIRCUIT DIAGRAM FOR CONNECTIONS OF HIGH SPEED CIRCUIT BREAKER

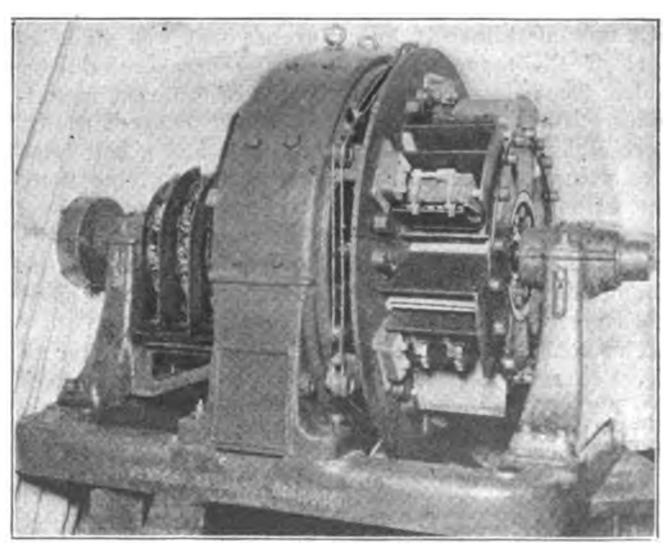
This breaker was used instead of the first type of circuit breaker, which has given successful operation during the past three years in the fourteen substations of the 440-mile original electrification of this road. The new breaker has the advantages of lower cost and

*Abstract of paper read at Pittsburgh meeting of the A.I.E.E., March 12, 1920.

†See issue of ELECTRIC RAILWAY JOURNAL for July 6, 1918, page 9.

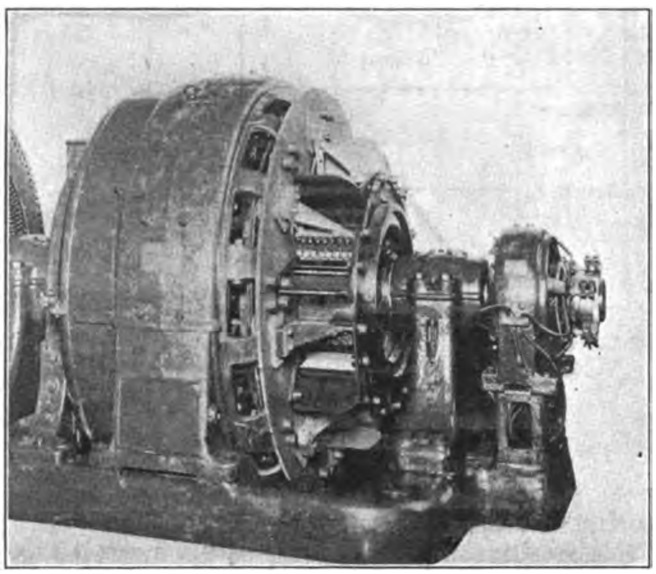


FLASH BARRIERS APPLIED TO SYNCHRONOUS CONVERTER



CONVERTER EQUIPPED WITH LATEST TYPE OF BRUSH HOLDER PROTECTION greater simplicity. One of these breakers is used with each of the 2,000-kw. 3,000-volt synchronous motor-generator sets in the Tacoma, Renton, Cathedral Falls, Hyak, and Cle Elum substations, and the remaining five breakers are placed one each on the new gearless passenger locomotives. On account of the lower cost of these breakers and the advantages of using the "unit" system throughout, each of the sets is protected by its own high-speed breaker instead of one breaker per substation, the arrangement in the original installation. The general connections, location of circuit breakers, etc., are shown in an accompanying diagram.‡ The circuit breakers for the substations and locomotives are exactly alike, with the exception of interlocking and calibration for tripping points.

The circuit breakers were given a very exhaustive test in connection with one of the 2,000-kw. sets before shipment. It was found that the generators could be short-circuited with only sufficient cable in circuit to connect the different meter shunts, short-circuiting contactors and high-speed breaker, without damaging



GENERATOR OF ST. PAUL MOTOR GENERATOR SET EQUIPPED WITH FLASH BARRIERS

the machine in any way and with practically no flashing at the brushes.

A special reliability or endurance test was made as part of the acceptance test of the breakers, during which about sixty-five short circuits of different magnitudes, fifteen of which were "dead" short circuits, were applied at intervals of about two and a half minutes without cleaning the commutators or giving them any attention whatever. At the conclusion of these tests, five "dead" short circuits were thrown on the sets within ten minutes. At the end of these tests the commutators were in excellent condition without need of cleaning or attention of any kind.

The application of the high-speed circuit breaker to direct-current electric locomotives is another distinctive advance, as, in addition to protecting the apparatus on the locomotive, it prevents the short circuits from affecting the substations.

An incidental advantage of this type of protection is the elimination of disturbances on the alternating-

‡This circuit breaker was described in the issue of the ELECTRIC RAILWAY JOURNAL for Feb. 21, 1920, p. 394.

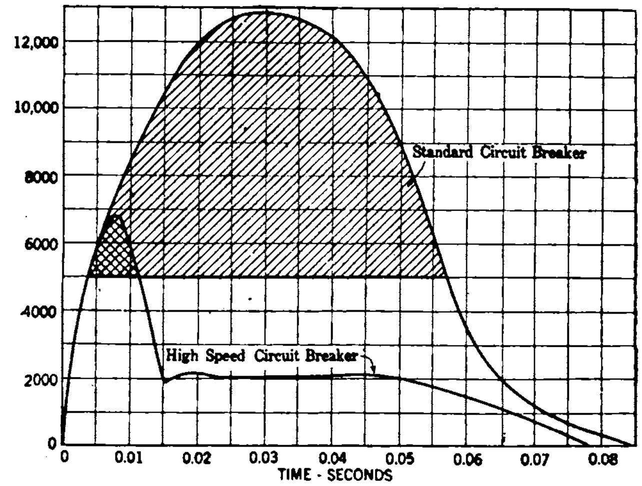


DIAGRAM SHOWING SHORT-CIRCUIT CURRENTS WITH STANDARD AND HIGH-SPEED TYPES OF CIRCUIT BREAKER

current side of synchronous converters or motor-generators sets ordinarily caused by direct-current short circuits, due to the fact that the load is decreased so quickly that momentum of the armatures supplies the energy and the load is not increased materially on the alternating-current side. The overload relays are therefore not affected, increasing very greatly the general operating efficiency of the substation, eliminating time required to start up a set from the alternating current side, etc. After the occurrence of a short circuit it is only necessary for the operator to close the high-speed circuit breakers and then the main switchboard breaker which is interlocked with the high-speed breaker, after which the main switch is thrown in following regular switching practice. If the short circuit still persists, the high-speed breaker will again open, but with no flashing or damage to brushes or commutators, and greatly increased duty on the regular breaker.

The flash barriers described in the original paper have not been changed in any essential details, improvements being along the line of simpler construction, ease of removal for inspection and improvement in appearance. An accompanying photograph shows the barriers as used on the generator of the Milwaukee electrification motor-generator sets, while another illustration shows barriers on a 600-1,200 volt, 60-cycle, 500-kw. synchronous converter.

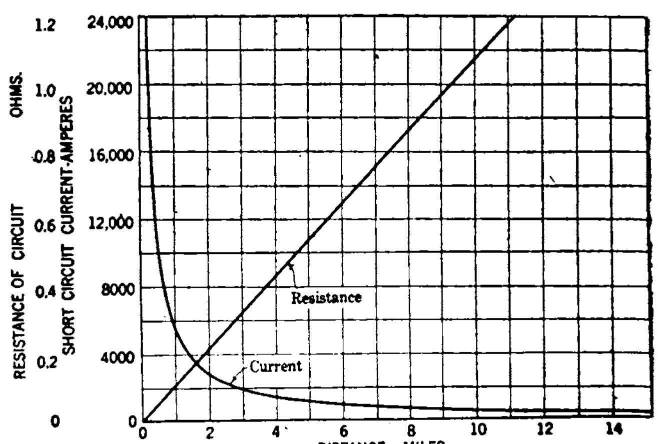


DIAGRAM SHOWING PROTECTION AFFORDED BY REMOTE TAP CONNECTIONS

Another advance in short-circuit protection is the protected type of brush holder in which the brush rigging is protected on all sides where flashing might occur, by asbestos lumber, so that an arc cannot readily hold between brush holders of opposite polarity. This protection is shown in a third photograph. It prevents the formation of iron or copper vapor, which might cause a flash to the frame and damage to the brush rigging or commutator. A removable cover is provided for inspection and removal of brushes. It is made of an iron sheet for convenience, as there is no tendency for the arc to strike this part of the brush rigging during tests or in actual operation. This type of brush rigging has been standardized for all 600-volt, 60-cycle, synchronous converters.

The use of the high-reluctance commutating poles is a very promising improvement which has just been made in 60-cycle, 600-volt synchronous converters, and has been standardized for all 60-cycle machines. This raises the flashing point at least 50 per cent.

In conclusion attention should be called to the great protection afforded by tapping the feeder at some distance from the substation. This is undoubtedly the cheapest type of protection which can be used, but cannot be relied upon to prevent flashing over under extreme short circuits. Under ordinary conditions the distance to the first tap need not be greater than 2,000 ft. A greater distance than this causes an appreciable loss of energy and drop in voltage. An accompanying diagram shows very clearly the great benefit of a small amount of resistance in reducing the maximum possible current on a short circuit.

If complete immunity is desired from short circuits, the high-speed circuit breaker and barriers offer undoubtedly the best known solution. With this protection feeder taps can be connected to the overhead trolley directly at the substation, reducing losses to a minimum. Maintenance of the substation apparatus will also be decreased, as burning from short-circuits undoubtedly causes most of the wear and deterioration on brushes and commutator. Another particular advantage of this type of protection is that it can be applied to old generators or synchronous converters of any voltage without changing the machine itself.

Flashing of 60-Cycle Rotary Converters*

The Author Analyzes the Causes of Flashing, Describes Experiments With a Number of Anti-Flashing Devices and Suggests Some Remedies for This Evil

BY M. W. SMITH

Engineering Department Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

THE protection of the 60-cycle converter from flashing is more difficult than that of commutating machines of any other class due to the inherent limitations of distance between neutral points on the commutator. This distance is fixed by the frequency and by the peripheral speed of the commutator.

The rate of increase of the direct current on short circuit is very rapid as compared with that in direct-current generators. Tests made of the generators of the 2,000-kw. sets for the Chicago, Milwaukee & St. Paul Railroad showed the initial rate of increase in current on short circuit to be approximately 1,100,000 amp. per second. On the 500-kw. converter, however, the average initial rate was approximately 3,300,000 amp. This rapid rate of increase in short-circuit current, together with the limited distance between brush-holder arms, makes the 60-cycle converter particularly susceptible to flashing trouble.

Flashing does not appear to be entirely dependent upon the value at which the current is arrested. When a machine is on short circuit a large percentage of the voltage is consumed internally. The heavier the short circuit, the larger is the percentage of the voltage thus consumed. Then so long as the direct current breaker is closed the voltage between brush arms, and hence the tendency to flash, is a minimum. The voltage between neutral points on extreme overload and short circuit with the direct-current breaker closed, is also dependent somewhat upon the brush pressure. Assuming a reasonable brush pressure and contact drop, it is practically impossible for a machine to "buck over" and hang on between arms on dead short circuit so long as the direct-current breaker is closed, for the voltage on the commutator is practically "killed." It is usually the opening of the direct-current breaker that does the damage.

FLASHING DEPENDS UPON SEVERAL FACTORS

An ideal circuit breaker is not necessarily one which opens the circuit before the machine "bucks over" (for it usually does not "buck over" until the breaker opens) or before the current reaches a certain value, but one which opens the circuit before sufficient gas and volatile matter have been formed over the commutator to cause the machine to "buck over" when the voltage is restored by the opening of the breaker. It may be said that flashing is roughly a function of the voltage, the distance between neutral points and the amount of gas or volatile matter over the commutator.

It is the writer's opinion, in view of results of very extensive tests, that a moderately high-speed breaker is no better than an ordinary slow-speed breaker. A very slow-speed breaker may even be better than a moderately high-speed breaker, due to the fact that the voltage will have time to die down appreciably before the breaker opens, especially if the alternating-current supply is opened in the meantime.

Opening the alternating current breaker is of course undesirable, because the machine has to be synchronized again. However, this procedure minimizes the flashing considerably.

The relative strength of armature and commutating-pole fields has a considerable influence upon the commutation, and hence upon the flashing of a synchronous converter on sudden changes of load and extreme overload or short circuit. Under normal load conditions the alternating-current magnetomotive force opposes that produced by the direct current. In the inter-polar space the resultant armature action is only about 15 per cent of the direct-current armature reaction and is in the same direction. The commutating-pole field ampere-turns under this condition are just sufficient to buck down this resultant magnetomotive force, and in addition to force sufficient flux across the commutating-pole gap to generate the required counter-voltage for commutation. At the instant of short circuit the con-

*Abstract of paper read at Pittsburgh meeting of the A.I.E.E., March 12, 1920.