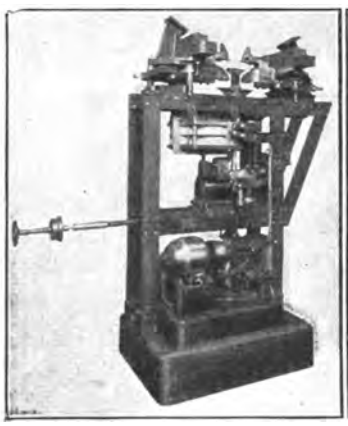
High-Speed Circuit Breaker Prevents Flash-overs on Milwaukee Electrification

With This Apparatus the Energy Waste Resulting from the Installation of a Permanent Resistance or an Increased Length of Feeder Cable to Reduce High Current Values Is Avoided

WHEN the decision to use high-tension direct current was made by the Chicago, Milwaukee & St. Paul Railway it was recognized that some means would have to be taken to prevent the flashover of the direct-current generators in case of a short-circuit on the overhead line. One suggestion made was that the company install resistance in the substations in series with the trolley circuit to cut down the current to a safe value. However, it was found that the construction of a suitable permanent resistance would be difficult and expensive; that the resistance would take up a great deal of room; and finally, that the energy waste would be appreciable. The electrification department, through R. Beeuwkes, electrical engineer, therefore favored the trial of some simpler and more economical method. To this end, the General Electric Company developed a high-speed breaker which was tested out at Schenectady on a motor-generator set made for the Milwaukee electrification.



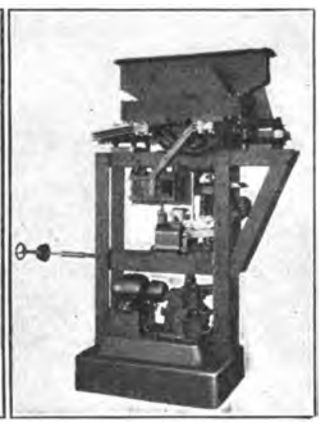


FIG. 1—HIGH-SPEED CIRCUIT BREAKER WITH ARC CHUTE REMOVED. FIG. 2—HIGH-SPEED CIRCUIT BREAKER WITH MAGNETIC BLOWOUT 3000 AMP., 3600 VOLTS

An auxiliary benefit of no mean value is the greater protection afforded to the company's telephone circuits which parallel the contact line. Since the installation of these breakers, the annoying acoustic shocks which previously occurred from short-circuits have disappeared. Notwithstanding the fact that this telephone line parallels both the 3000-volt direct-current contact line 40 ft. away and the 100,000-volt alternating-current transmission line 80 ft. away, the operation of the telephones is very satisfactory.

No attempt was made to eliminate inductive interference other than fully to transpose the weak-current circuits for varying lengths; to see that the insulation was in good condition; and finally, to install fuses in the circuits at the stations—both the Missoula and Rocky Mountain division—where telephone and telegraph circuits are located. There are no transpositions on the high-tension line.

FUNCTIONS AND OPERATION OF THE HIGH-SPEED CIRCUIT BREAKER

The function of the high-speed circuit breaker hereafter described is to operate with sufficient speed to check the rise in current caused by a short-circuit before damage can be done to the converting equipment. In order to meet this requirement, it is necessary that the rise in current be checked within a few thousandths of a second, and the circuit breaker described below meets these conditions in every respect. The rate of acceleration on the main and secondary contacts is approximately 8000 ft. per second and they are released in a time as short as 0.003 second or less from the beginning of a short-circuit. The time from the beginning of the rise in current caused by a short-circuit until the secondary contacts part has been shown by test to be of the order of 0.004 second. This compares with about 0.10 to 0.15 second, the speed of ordinary switchboard type breakers. The designers have thus succeeded in building a breaker which will in effect foresee the rise in current caused by a short-circuit and insert sufficient resistance to limit this rise to a safe value.

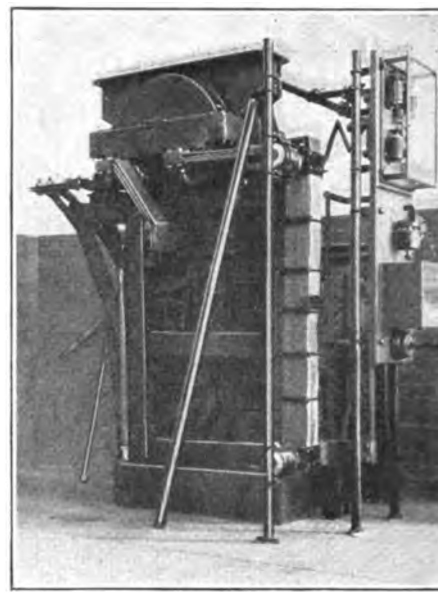


FIG. 3—HIGH-SPEED CIRCUIT BREAKER INSTALLED IN JANNEY SUBSTATION, CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

It has been the practice on many railroads to install a certain amount of feeder as resistance between the substation and the tapping-in point usually by carrying out the feeders to some distance from the station before tapping in. It was evident, therefore, that if apparatus could be developed to protect the generators from flashover on severe short-circuits, it would permit of the feeders being tapped directly to the trolley at the substation, thus eliminating the losses due to feeder resistance.

Preliminary calculations in connection with the electrification of the Chicago, Milwaukee & St. Paul Railway showed that quite an appreciable amount of power could be saved each year by the elimination of this extra feeder resistance. Work was therefore initiated on the development of an air circuit breaker which would have such a high speed in opening that it could be used to insert resistance in the circuit soon enough to prevent the

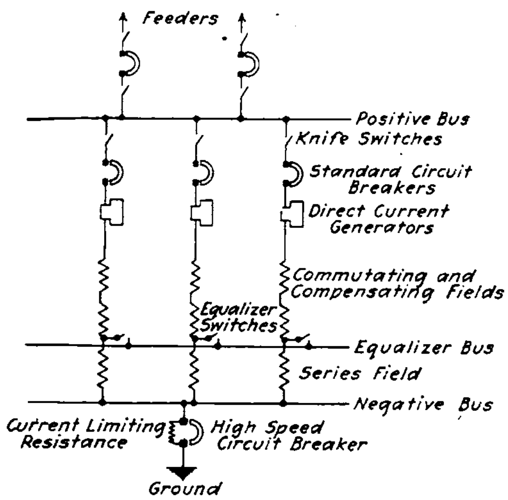


FIG. 4—D.C. CONNECTIONS FOR SUBSTATIONS WITH THREE MOTOR-GENERATOR SETS PROTECTED BY HIGH-SPEED CIRCUIT BREAKER

short-circuit current from reaching such a value as to cause the direct-current machinery to flash over. This design of breaker required a speed much faster than anything ever before attempted. Careful investigations demonstrated that the device must operate in a shorter time than is required for one commutator bar to pass from one brush to the next or less than one-half cycle for that particular machine.

One of these breakers is installed in each substation and connected into the negative return circuit between the ground and the negative bus, as shown in Fig. 4. This location affords the maximum protection, since the return circuit must pass through the limiting resistance in case of a flashover from the positive to ground, as all of the negative terminals, bus rigging, etc., are insulated for full generator voltage. To insure complete protection the high-speed breaker is so interlocked with the regular switchboard type of air

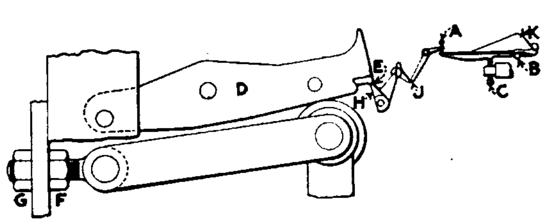


FIG. 5—DIAGRAM OF LEVERS FOR TRIPPING AND RESETTING THE TYPE MW CIRCUIT BREAKER

circuit breaker that the high-speed breaker must always be closed before the switchboard breakers.

The fourteen 3000-volt direct-current substations on the Chicago, Milwaukee & St. Paul Railway are equipped with this new type of breaker, and the first units installed have been in operation since early in 1917 with very satisfactory results. All substation feeders are tapped to the overhead trolley system directly at the substation, eliminating the resistance losses occasioned by tapping at some distance away. Actual operation has demonstrated that it is entirely practicable to operate direct-current stations in this manner when protected by the high-speed circuit breaker, even though the voltage of the system (3000 volts) is the highest direct-current voltage used in commercial railway work.

Circuit Breaker Is Mounted on an Insulated Framework

The high-speed circuit breaker installed for the Chicago, Milwaukee & St. Paul Railway is of the single pole, magnetic blowout type rated 3600 volts, 3000 amp., direct current. The breaker and mechanism for a self-contained unit are mounted on a structural iron framework with cast-iron base. The base and framework are in turn mounted on an insulated base to insulate the circuit breaker from the station floor. The operating mechanism is so arranged that the breaker can be closed either by hand at the breaker or by a motor controlled from the station switchboard. The closing of the breaker by means of the motor is accomplished by a

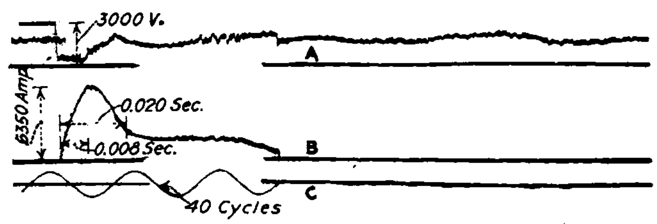


FIG. 6—OSCILLOGRAPH RECORD OF SHORT-CIRCUIT ON MOTOR-GENERATOR SET CHECKED BY HIGH-SPEED CIRCUIT BREAKER

Curve *A*—Voltage across generator terminals 1 mm.=143 volts.
Curve *B*—Current positive terminal of generator 1 mm.=174 amp.
Curve *C*—Timing wave 40 cycles.

cam mechanism operated through gears. When closed by hand, a ratchet mechanism is used.

The main contacts are of the well-known laminated brush type, the brushes forming the stationary contacts. The movable contact is a solid copper forging which is made as light as possible in order to reduce to a minimum the mass to be moved in operation. Secondary contacts are located above the main contacts and are of very ingenious design to insure their breaking after the main contacts in order to prevent any possibility of burning the current-carrying parts of the main contact. All of the contacts are located in a blowout chute of insulating material designed to withstand the burning incident to the arc. The blowout magnet is of laminated iron of large section. The blowout coils and trip coils are connected in series so that the blowout coils are excited at all times, as the usual arrangement of shunt blowout coils was found to give insufficient speed of blowout. The main and secondary contacts are carried on a lever and this lever is actuated by a nest of compression springs which exert a force of about 8000 lb. when the breaker is adjusted for operation. It was found that this pressure was required to give the rapid acceleration necessitated by the high-speed conditions under which this circuit breaker is required to operate.

The tripping is accomplished through a train of latches and levers actuated by a solenoid, the magnet frame and core of which is specially laminated to obtain a quick magnetic response to the short-circuit current. The object in using a series of several latches is to allow the mechanism to move the main latch through a distance of ⅛ in. or more by means of a solenoid. This solenoid, in order to act in the time required, is able to move only a distance of about 0.001 of an inch and can exert a force of only about 200 lb., while the main latch is subject to a pressure of about 4000 lb. transmitted through a lever from the compression spring above referred to.

In order to take care of the varying number of units in the several stations, the calibration is obtained by means of an adjustable tension spring directly opposing the pull of the solenoid. Referring to Fig. 5, the actual tripping takes place at *J*. The levers *A* and *K* are for multiplying the movement of the solenoid, which delivers its force at *B* so as to obtain a movement large enough to be entirely definite. The latches from *E* to *J* are special forms of levers which reduce the great pressure at *E* to a value which can be handled by a small bearing surface at *J*.

Upon the opening of the breaker contacts, the resistance becomes increasingly effective due to the resistance of the arc as the breaker completes its operation and after the lapse of about eight-thousandths of a second or less from the beginning of the short-circuit (see oscillograph record, Fig. 6), the resistance has increased to such a value that no further rise of current can take place.

This method of protection has given such satisfactory results that high-speed circuit breakers have been adopted by the General Electric Company as standard on all 3000-volt direct-current generating apparatus for steam road electrification. Actual service has demonstrated that the high-speed breaker will protect the generating apparatus from all short-circuits experienced, and not only will prevent damage to the brush rigging, commutator, etc., but will relieve the duty on the regular switchboard air circuit breakers.

The oscillograph record shown in Fig. 6 gives a good idea of the remarkably high operating speed of this circuit breaker and the resulting protection against damage to equipment. It may also be noted that this oscillogram shows the maximum current rise of less than ten times normal which is quickly reduced to well within the commutating capacity of the machine. With this method of protection, none of the effects of the direct-current short-circuits is transmitted through the set to the alternating-current side, thereby preventing such disturbances from affecting in any way the alternating-current supply system.

Modern Cars Speed Up Car Loading

THE value of a well-designed car from the standpoint of ability to load quickly and, therefore, to maintain a high schedule speed, or conversely, to operate a greater number of car-miles for a given platform expense, is well shown by some tests made recently by C. D. Smith, superintendent of transportation Mahoning & Shenango Railway & Light Company, Youngstown, Ohio. The loading times expressed in seconds per passenger were found to be as follows: Peter Witt car, 0.9 second; standard-type car with doors at both ends, 1.35 second, and high-floor center-entrance car, 1.5 second.

These cars are roughly of the same seating capacity. The Peter Witt cars were of the lot of thirteen delivered to the company last September. The data were taken at the Public Square in Youngstown, from which point all cars start their runs. During the rush-hour period the passenger interchange at this point is very heavy.

Safety Education Reduces Accidents

The Worcester Meeting of the American Society of Mechanical Engineers Was Devoted to a Discussion of the Safety Movement

IN VIEW of the draft made on the gross earnings of electric railways by accident claims, some of the discussions presented at the Safety Education Session of the American Society of Mechanical Engineers at its recent Worcester meeting should be of interest to electric railway men. In a paper by L. A. DeBlois, safety engineer E. I. du Pont de Nemours & Company, Wilmington, Del., it was brought out that safety engineering is more than merely a matter of safeguarding and advertising. An analysis of industrial accidents shows that from 15 per cent to 25 per cent are of the so-called "unavoidable" class.

Of the remainder, or avoidable accidents, between 10 per cent and 20 per cent are caused by unsafe mechanical or structural conditions and are therefore possible of correction. From 80 per cent to 90 per cent are attributable to human defects, that is, to ignorance, carelessness, irresponsibility, indifference, disobedience, recklessness, horse play and inexperience, and to defects of system, such as lack of proper supervision, discipline, etc., in the organization. The remarkable thing about the above figures are that they seem to apply equally well to all industries, being practically the same for such industries as explosives manufacturing, cement making, mining, railroading, and others in which it is usually considered that the life hazards are widely different.

So far as the structures with which the railway industry is concerned it was pointed out that stairs, handrails and narrow aisles are common causes of accidents. In the shop, insufficient headroom making machines, valves, etc., difficult to get at for repairs and manipulation are also fruitful accident producers. In connection with machinery it was pointed out that no machine can be made absolutely foolproof even in its regular operation and that conditions occur during adjustment, oiling, cleaning, repairs, etc., under which even the best safeguards may be either absolutely useless or introduce hazards of their own.

As the human element offers the greatest opportunity in the way of accident reduction the stress evidently should be placed upon the education and training of the individual workers in the matter of safe practices and the conditions which constitute hazardous operation. The organization of a safety department with a capable safety engineer or inspector was advocated. The men in charge of this safety work should be more than mere workmen transferred to a new job and should have the full backing of the higher executive officers.