HIGH TENSION SWITCHING EQUIPMENT

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The dividing line between the relative terms "low-tension" and "high-tension" can well be established at the voltage where a decided change occurs in the character and design of the connected apparatus. In the introduction of this article the author names the distinguishing voltage values for alternating current and direct current. The first half of the article he then devotes to a general discussion of the adverse conditions that have been met in producing successful indoor and outdoor switching equipments and of the design features that have rendered their operation reliable. In the remaining half of the article he describes the switching and control equipment employed by a typical large power company that distributes its output in large blocks.—Editor.

As a distinction between high and low tension equipment, we will draw an arbitrary line at 22,000 volts a-c. and 750 volts d-c., because it is at these points that there is a marked change in the character and type of the apparatus which is recommended for station and switchboard installations.

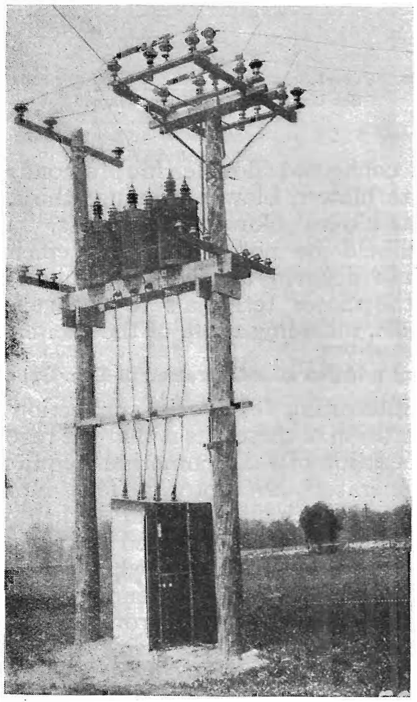

Fig. 1. Belleville Outdoor Substation, Eastern Michigan Edison Company for Supplying 75 kv-a. at 2300 Volts Three-phase from a 23,000-volt Transmission Line

The upper limit for high tension installations has probably not as yet been reached, and without attempting to make any predictions for the future, it can be stated that at present the limits of practical operating voltage are 155,000 volts a-c. and 3600 volts d-c. Higher voltages have been discussed and considered and experimental apparatus has been built and tested, but at this writing there is no immediate prospect of higher voltages being used.

High tension d-c. apparatus is invariably installed indoors because circuit breakers and other necessary control devices cannot be properly protected out of doors.

Fig. 2. 135,000-volt High Altitude Interdepartmental Standard Bushing with Fittings, for Oil Circuit Breaker

For a-c. operation up to and including 22,000 volts, it is usual, although not invariable, to place the switching equipment indoors, whether at generating or large distributing stations, space factors being influenced more by the size of the generating units than by the size of the switching equipment. Above 22,000 volts, however, it has

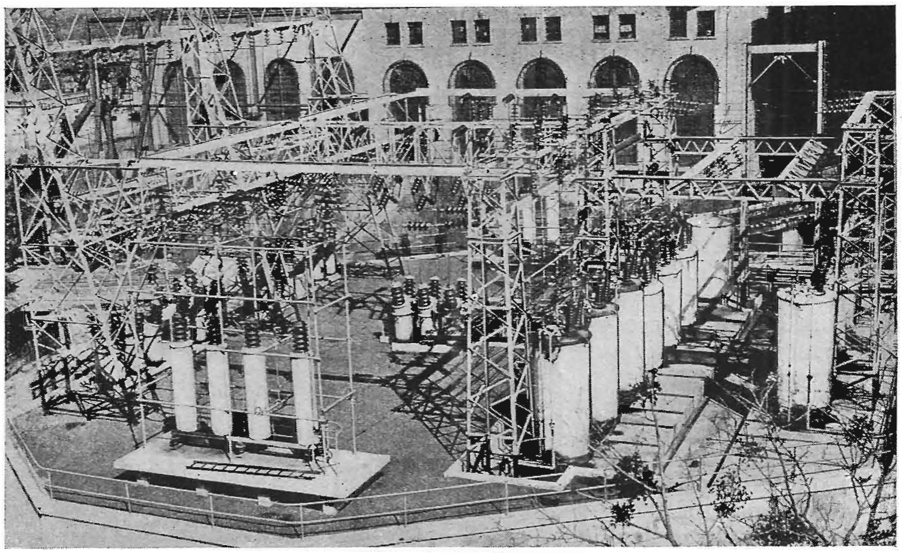

Fig. 3. Outdoor Substation 60,000/2400-volt, Ft. Worth Power & Light Company, Fort Worth Texas

been found advisable to install many high tension equipments out of doors, as the space factors involved in the higher voltages, 45,000, 70,000, 110,000 and 150,000 volts, are of such magnitude that the indoor installation of apparatus seriously affects station expense.

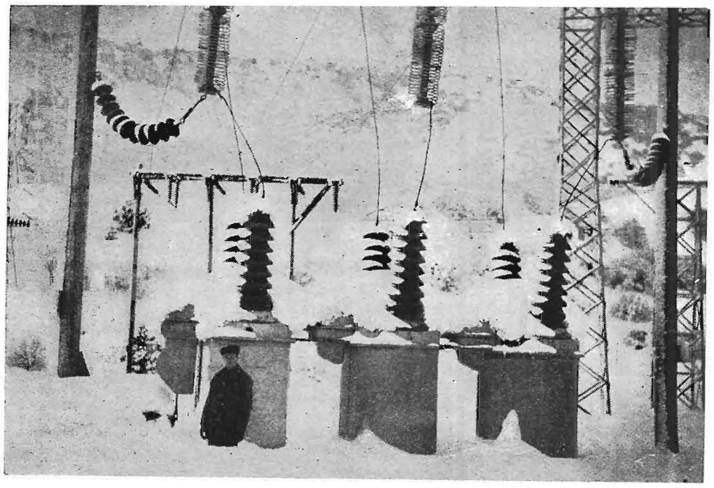

Fig. 4. Oneida Development Switch Yard. Snow on 130,000-Volt Oil Switch in Service, February 15, 1916

Roof and wall entrance bushings for these high tension installations are also very expensive and introduce complications in station design that are avoided when the apparatus is located out of doors.

Practically all high tension equipment is operated from a control board which can be located at any convenient distance from the apparatus itself. It is therefore usual in high tension equipments to find the control switchboards and the low tension equipment under cover, and the high tension equipment including transformers, disconnecting switches, oil circuit breakers and lightning arresters, out of doors. These outdoor installations vary from a substation of small capacity, as illustrated in Fig. 1, to the very elaborate distributing station, such as illustrated in Fig. 3.

The same attention is given to the design of these outdoor distributing stations as is given to those stations where the apparatus is all installed indoors. The steel framework must be substantial for it must carry the line strains, wind pressures and sleet weights which become of serious moment in many localities. It is also necessary to so design the steel structure that the incoming and outgoing lines can be arranged for simple operation and ready inspection. Transfers from one line to another must be easily and quickly made and increased space factors must be used to allow for weather conditions which are not provided for in the indoor installations.

It is interesting to note that outdoor switching apparatus, contrary to the expectation of many designing and operating engineers, has given less trouble in actual operation than the same voltage apparatus which has been installed indoors. This can be partially explained because moisture is the principal cause of difficulties with electrical apparatus and moisture is more quickly dissipated outdoors than indoors and in apparatus where oil is the principal insulating medium it is only necessary to keep the moisture from the oil to insure successful operation.

Fig. 4 serves to illustrate the severe weather conditions which are frequently present in those localities where outdoor apparatus is used. It was because of these known conditions that the designing and operating engineers were cautious in the use of outdoor apparatus and it is all the more to their credit that they have been able to design apparatus which properly performs its functions, even under such adverse conditions.

For installations of 110,000 volts and above at altitudes over 2500 ft., it is common practice to furnish specially designed switching equipment, and the special bushing for this purpose is illustrated in Fig. 2. These longer bushings are used to give arc over values which the higher altitudes make necessary. To obtain the best results from high tension control equipment it is now considered good engineering practice to specify that the bushings shall have an arc over value less than the puncture value, and installations where this specification has been applied have been remarkably free from interruption difficulties.

High tension switching equipment is not always placed out of doors. The most marked instance of an installation of indoor equipment, modern in type, is that at Keokuk and partially shown in Fig. 5. All busbars and connections are open to inspection, in some cases barriers separating the phases and isolating the circuits. The disconnecting switches are of simpler design than those of outdoor equipments because here weather protection is not required. It will be noted that the oil circuit breakers do not vary materially in appearance from those

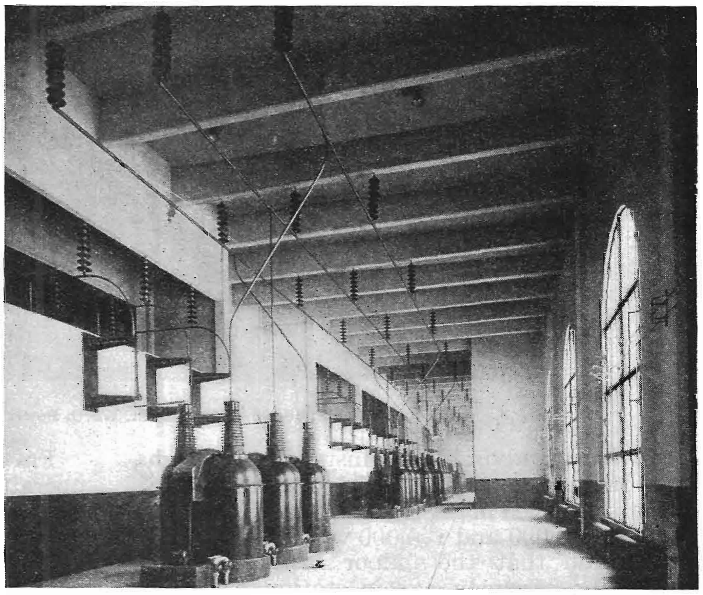

Fig. 5. Section of a High Tension Room, Mississippi River Power Company

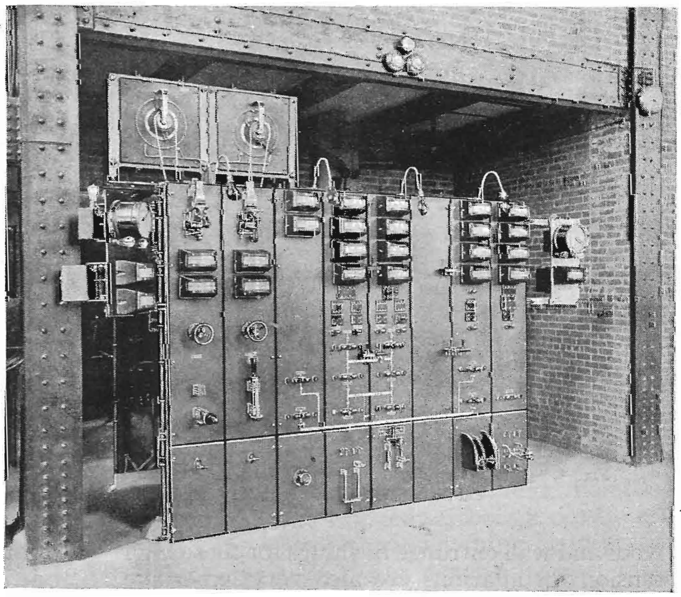

Fig. 6. Main Switchboard in Ingham Mills, New York Power Station, East Creek Electric Light & Power Company

which are installed out of doors except in the design of the bushings.

The control boards for high tension apparatus, which are always located indoors, vary in many particulars. Typical illustrations are given in Figs. 6, 7, 8 and 9.

There are two distinct types of high tension transmission; one where it is necessary to distribute the output in small units, such as the systems of the western operating companies where irrigation and small community loads are the principal items, and others like the Montana Power Company which delivers large amounts of power to given points for distribution in large units. A description of the switching equipment of the last named company follows:

Fig. 10 shows in general the system of connections of the Power Company. Some of the smaller substations are not shown, nor the power station of the allied system of the Thompson Falls Power Company. This station will eventually feed into the system of the Montana Power Company.

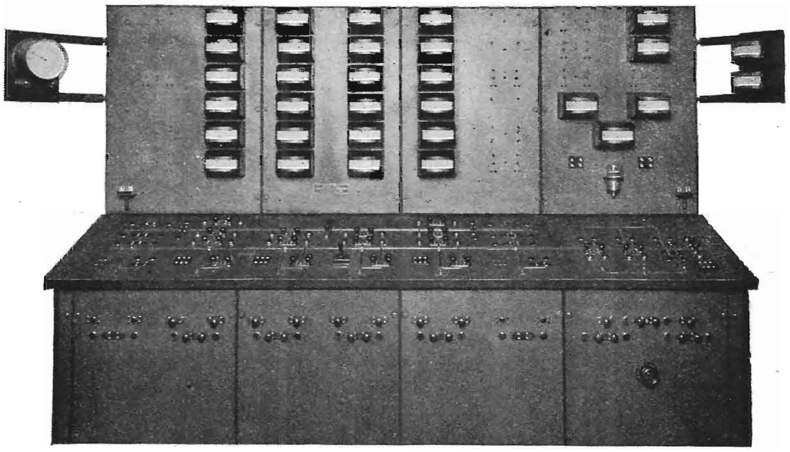

Fig. 8. Alternating-current Closed Type Benchboard

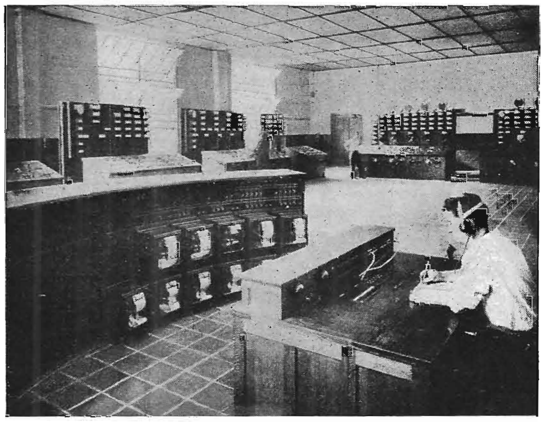

Fig. 9. Control Switchboard, Mississippi River Power Company, Keokuk, Iowa

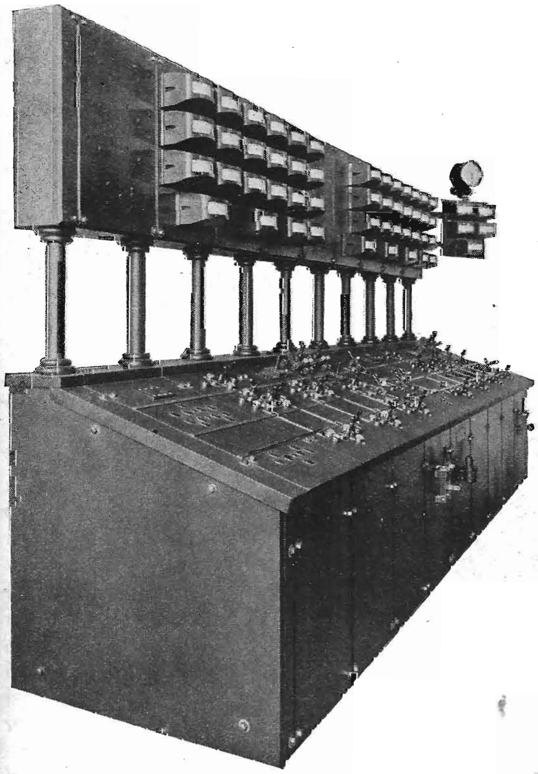

Fig. 7. Gallery Type A-c Benchboard

In addition to approximately eight hundred miles of transmission of the Power Company, there is shown nearly two hundred miles of transmission of the Chicago, Milwaukee & St. Paul Railway Company, which receives power from the Montana Power Company. The railway company's lines are now being extended some two hundred miles more.

The main power plants are at Great Falls, Montana, and are known as the Rainbow and Volta plants, which have generating capacity respectively of 21,000 and 40,000

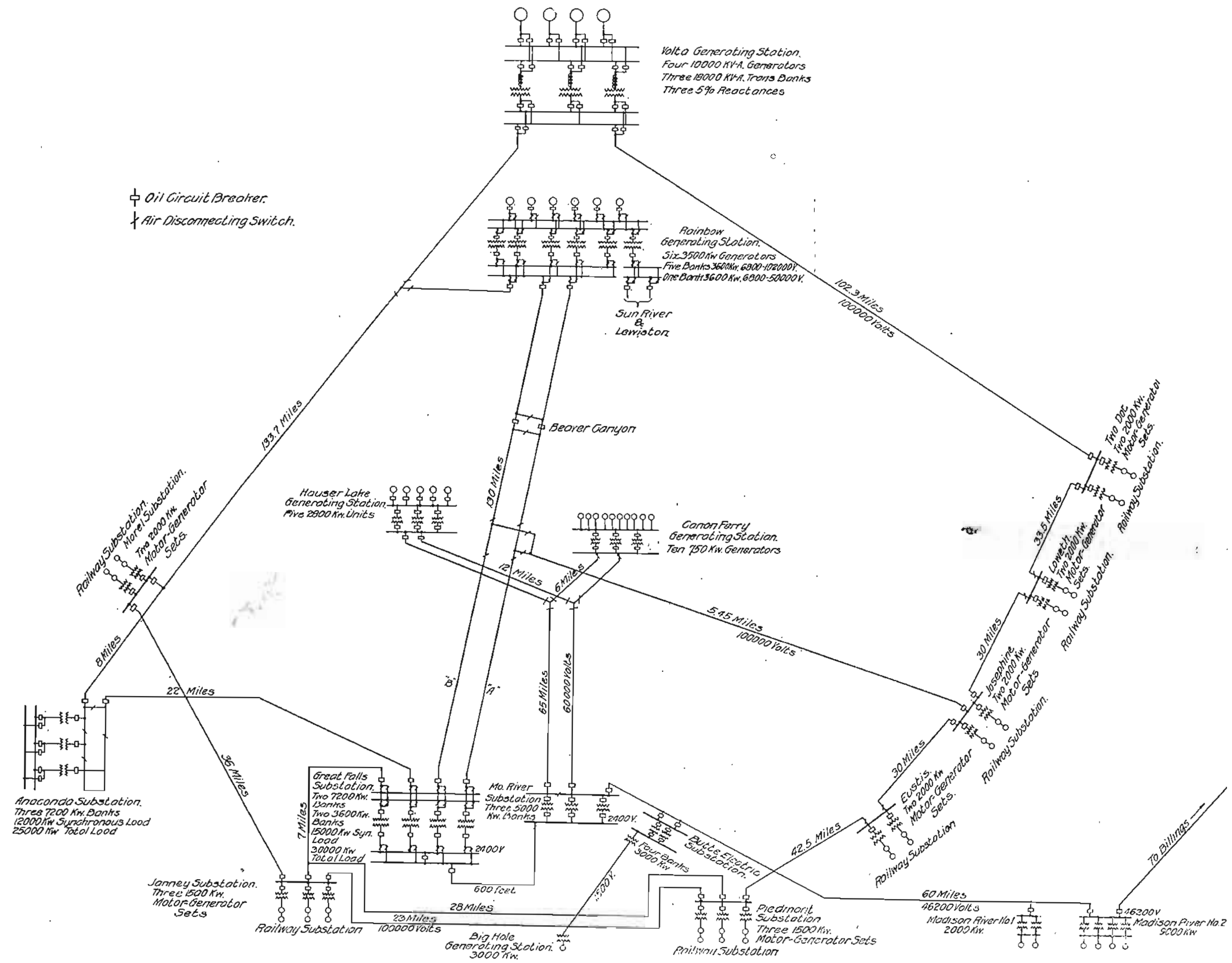

Fig. 10. Distribution System of the Montana Power Company

kw. In both of these stations, the power is stepped up to 100,000 volts and transmitted to the main distributing station at Butte and to the railway company's substations.

The Power Company also generates power at several smaller stations, namely, at Hauser Lake, Cañon Ferry, at two stations known as Madison River No. 1, and No. 2, and at the Big Hole Station. The first two stations transmit power at 60,000 volts, the Madison River Stations at 46,200 volts, and the Big Hole at 15,000 volts. All the power stations are tied together either by direct connection, or through the various substations at Butte, where a large amount of energy is used in the mines.

Besides the substations at Butte, there is a large substation at Anaconda, used to supply power to the smelters and for the 2400-volt d-c. railroad between Butte and Anaconda, known as the Butte, Anaconda, & Pacific Railway, and the substations of the Chicago, Milwaukee & St. Paul, of which there are seven in operation, and seven more nearing completion.

The Volta plant is a modern plant in every way, and the switching equipment is representative of successful up-to-date practice. Figs. 11, 12 and 13 show some views of the switchboard and equipment. Fig. 14 shows a view of the Rainbow Plant. Figs. 15, 16 and 17 show some views of the main distributing substation at Butte.

One of the features of the Volta plant is the special design of disconnecting switches. The use of the ordinary knifeblade disconnecting switch operated by a hook on the end of a long rod was practically prohibitive on account of the narrowness of the space where the operator would have to stand, in relation to the height of the disconnecting switch. The special switch designed to meet the condition is shown in Fig. 18. This switch is operated from directly below, whereas, with the ordinary switch, the operator must have his rod at a considerable angle to open or close the switch.

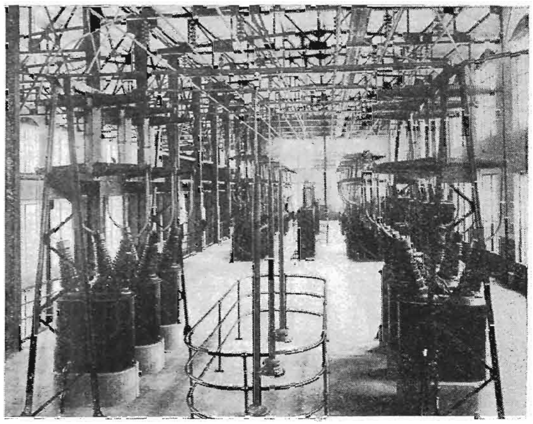

Fig. 12. 100,000-volt Switches, Volta Plant, Montana Power Company, Great Falls, Montana

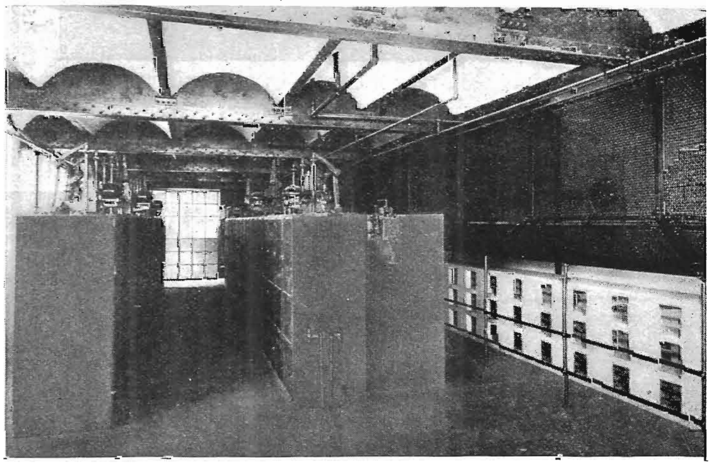

Fig. 13. 6600-volt Switches and Busses, Volta Plant, Montana Power Company, Great Falls, Montana

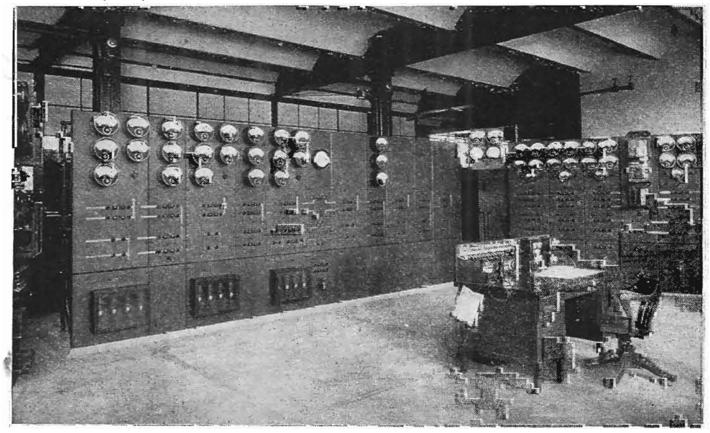

Fig. 11. Main Switchboard, Volta Plant, Montana Power Co., Great Falls, Montana

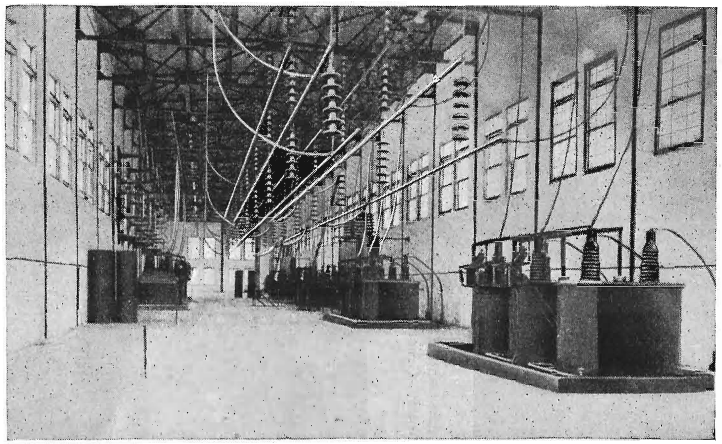

Fig. 14. Rainbow Plant, High Tension Room Containing Oil Switches, Lightning Arresters and Busbars, Great Falls Power Company

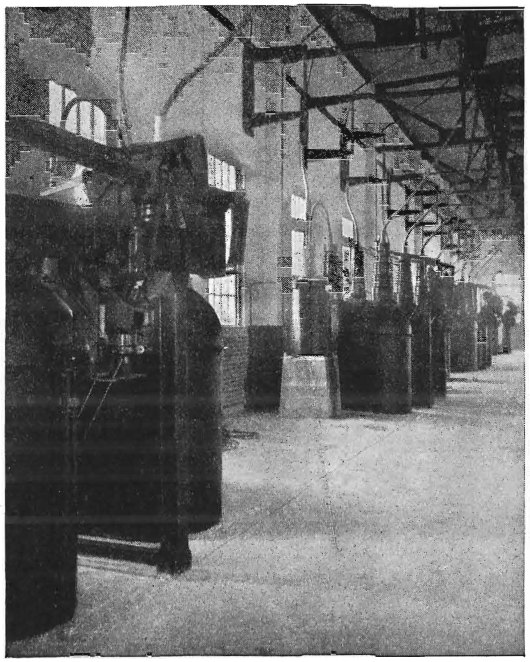

Fig. 15. Butte Substation Showing 100,000-volt Line Switches

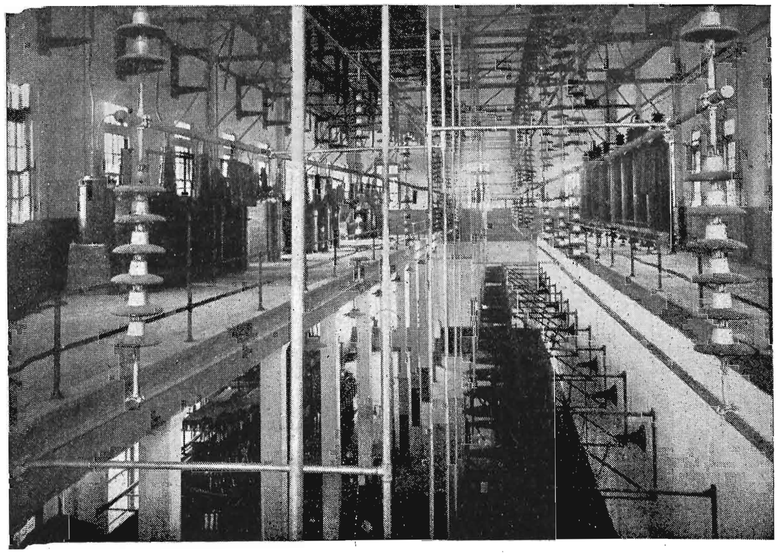

Fig. 16. Butte Substation, Showing 100,000-volt Bus Construction, Great Falls Power Company

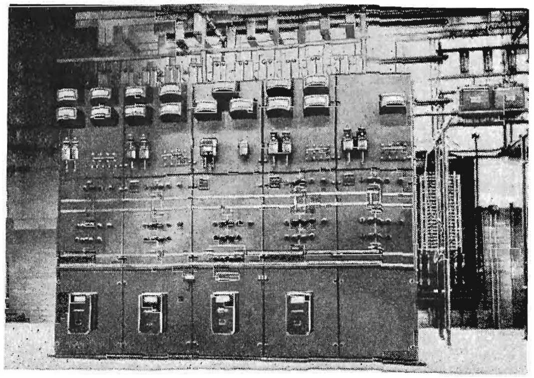

Fig. 17. High Tension Control Board in Substation, Great Falls Water Power & Townsite Co., Butte, Montana

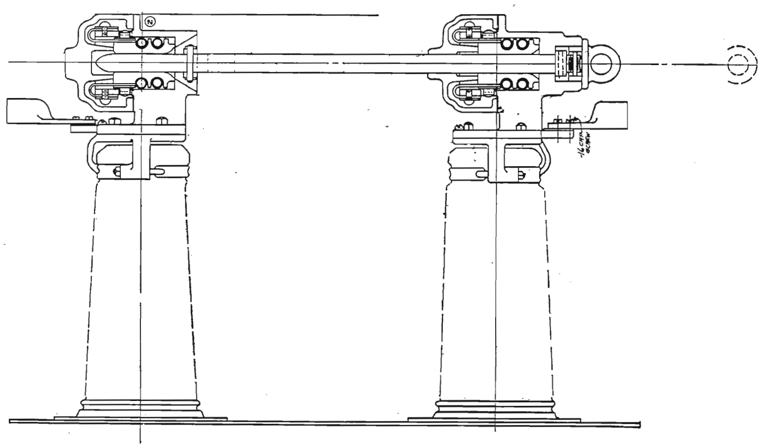

Fig. 18. Special Disconnecting Switch for Restricted Quarters

The substations of the railway company have the usual high tension a-c. equipment including lightning arresters, roof entrance bushings, instruments, transformers, and oil circuit breakers. The circuit breakers are hand-operated from a handle in the main switchboard room, which is separated from the high tension room, see Fig. 19.

When these substations were installed, there arose the difficult problem of arranging the automatic overload protective devices, so that trouble on the railway system would not shut down the power company's lines, and vice versa. This was accomplished after weeks of study, by a system of interconnecting relays, so that the relays, which are of the two-coil dynamometer type, will operate only with a certain relative direction of power flowing in the power company's and the railway company's lines.

The d-c. end of these stations is extremely interesting, being of the highest voltage

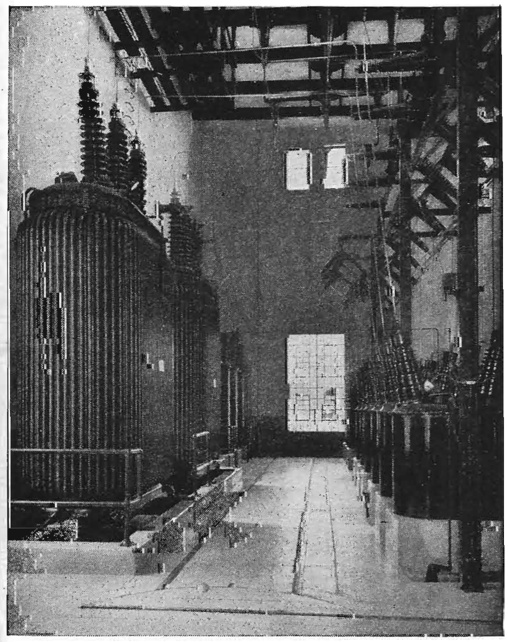

Fig. 19. Chicago, Milwaukee & St. Paul 3000-volt D-c. Electrification Two 2500-kv-a. Three-phase 100,000/2300-volt Transformers and Oil Switches in Morel Substation

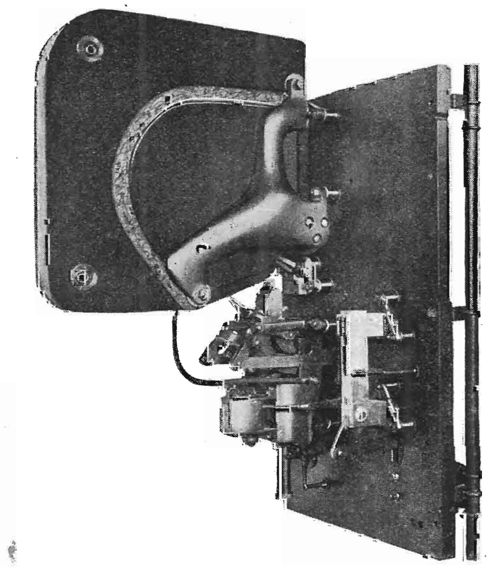

Fig. 20. 1500-amp., 3600-volt D-c. Automatic Circuit Breaker and Lever Switch

regularly used for railway operation, viz., 3,000 volts. The most important feature of the switching installation is the circuit breaker design. The breaking of an arc at 3000 volts d-c. presented a serious problem, but after considerable experimenting a magnetic blowout circuit breaker, as illustrated in Fig. 20, was developed. The blowout chute had to be very large, and of a shape which was determined by many tests. The circuit breakers have now been in successful operation for some time.

The general arrangement of the d-c. switchboard is shown in Fig. 21. The circuit breakers are out of ordinary reach, and the ammeters have protecting covers, making the switchboard safe for the attendant. Other special features of the d-c. board are the d-c. reverse current relays for changing the series field connection of the d-c. generators when regeneration takes place (that is, when trains feed power back to the line on going down grade), and the voltage killing device for lowering the d-c. voltage at time of short circuit, by automatically connecting a resistance in series with the generator field.

In all high tension equipment design it has been the aim of the engineer to so arrange the apparatus that it would be free from accidental contact, easy to inspect, easily replaced when it was necessary to overhaul or renew worn parts, and as far as possible, so designed that a single operator could inspect any device with safety and without assistance from others. Where "safety-first" is a desirable aim in apparatus of low voltage, it becomes an absolute necessity for voltages of the higher values.

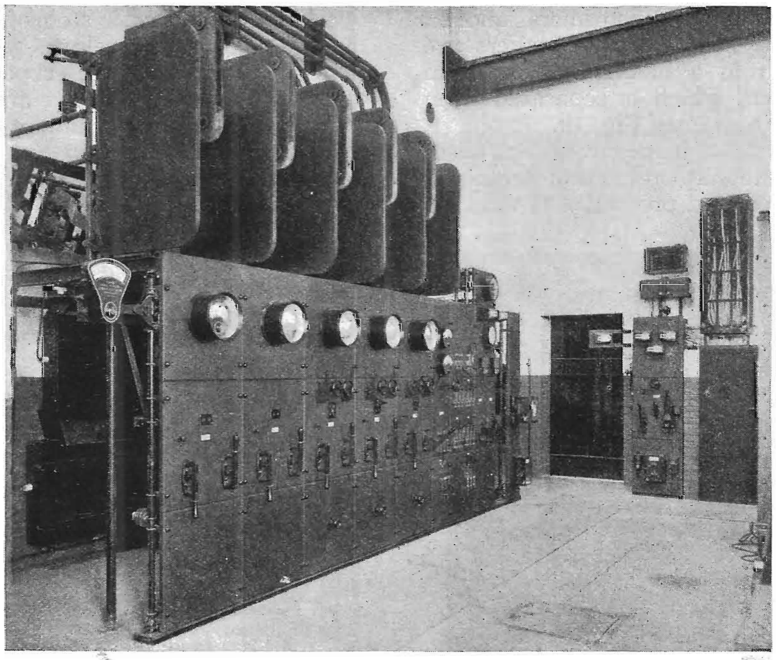

Fig. 21. Chicago, Milwaukee & St. Paul 3000-volt D-c. Electrification. Switchboard Controlling Three 1500-kw., 3000-volt D-c. Motor-generator Sets and Outgoing Feeders, Piedmont Substations

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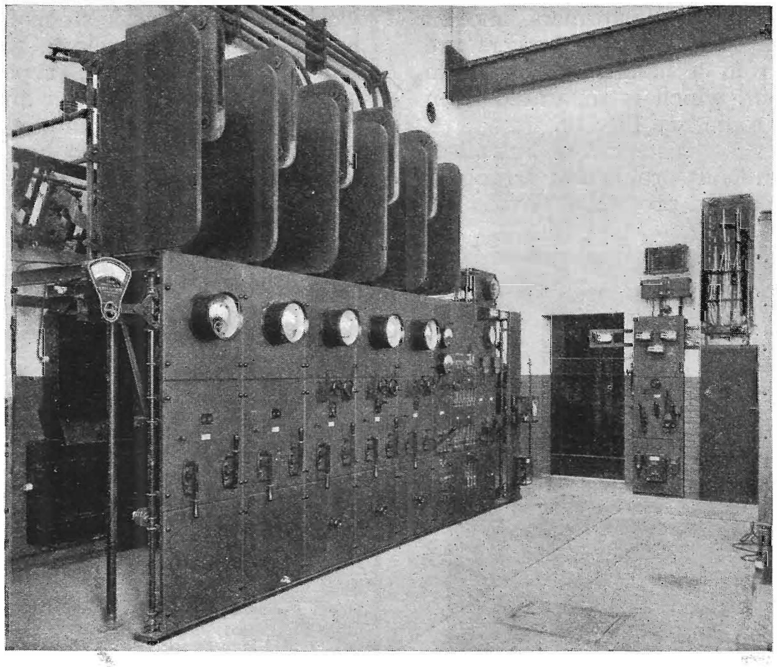

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