SUBSTATIONS OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY ELECTRIFICATION

By A. Smith

Construction Engineering Department, General Electric Company

This contribution comprises a brief description of the St. Paul substations, dealing with the general arrangements of the building and apparatus and the principal features of construction. Special attention was paid to facilitating the handling of apparatus and the ease of operation in designing the layout.—Editor.

General Arrangements

The fourteen substations, distributed along the 440 miles of electrification, differ only in the number and capacity of units and high tension transmission lines. Substations serving heavy grades contain three 1500-kw. motor-generator sets with their corresponding three-phase stepdown transformers. The remaining stations contain two 2000-kw. units with transformers. One unit in each station is held as a spare, thus, the stations are really of 3000- and 2000-kw. capacity respectively.

Each substation building, as will be noted from representative views, Figs. 1, 2 and 3, consists of a short and comparatively low building, housing the motor-generators and low tension switching equipment, and a longer and higher building contiguous thereto for the high tension transformers and switching equipment. All of the a-c. and d-c. switchboard panels, the power limiting apparatus, signal and lighting transformers, the negative quick acting circuit breaker and the low tension running and starting switches for the synchronous motors are located in the main generator room. The 100,000-volt oil switches and the lightning arrester tanks, together with all high tension wiring, are located in the transformer room. The lightning arrester horn gaps are mounted on the roof of the high tension room, except in three stations, where, due to the heavy snow loads, the roofs were constructed in gable form, whence the arrester horn gaps were mounted inside the building.

Power is supplied from the Montana Power Company through four 100,000-volt transmission lines. Such substations as are provided with an incoming transmission line are equipped with two oil switches on the railway company's high tension tie line, which parallels the track and connects all of the substations together. Stations being served exclusively from this tie line are connected through horn gap air break switches located on the roof of the building. By referring to Fig. 4, which shows the general system of connections, it will be noted that the high tension bus practically forms a part of the high tension tie line and that but one lightning arrester is employed in each station. The motor-generator transformers are fed from these busses through oil switches of the

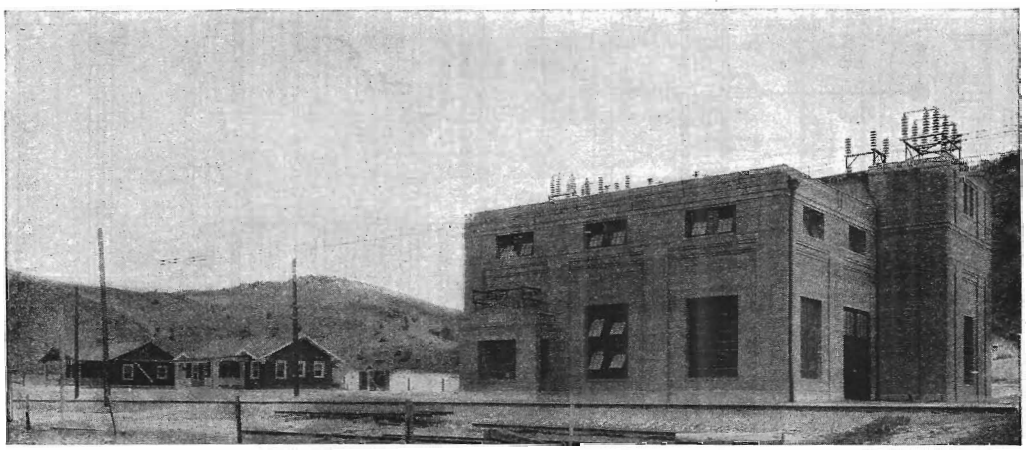

Fig. 1. Substation No. 4 at Eustis

K-21 type, while the 2300-volt secondaries on these transformers, together with the starting taps, are controlled from "running" and "starting" oil switches mounted in cells built into the dividing wall between the two rooms The direct current conductors from the motor-generator sets are carried to the 3000-volt d-c. switchboard located at one end of the building from which point it is distributed through the feeders running east and west.

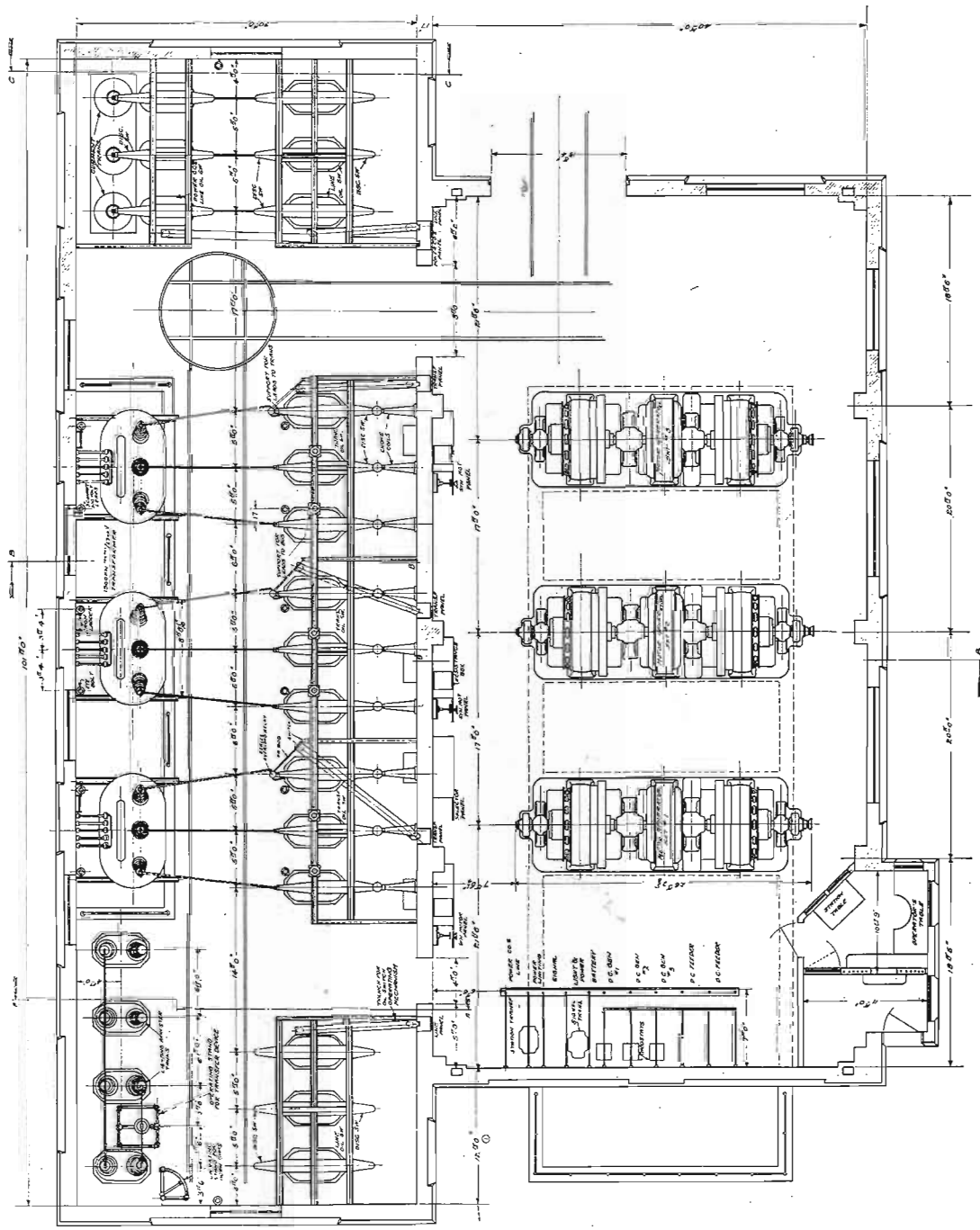

Fig. 2. Arrangement Plan of Piedmont and Janney Substations, 100,000-volt Alternating Current, 3000-volt Direct Current, 31,500-kw. Sets.

A selector oil switch provides means for connecting the signal and lighting supply to the secondary of either of the two main transformers.

Building Construction

The buildings are constructed of a very good grade of brick resting on concrete bench wall. The flat roof construction with parapet wall was adopted as standard and employed in all cases except for stations in localities sub ect to extremely heavy snow-falls. For the latter it was considered advisable to resort to the gable roof construction. The roof of the transformer room is of plain "I" beam construction, but for the motor-generator room, which is considerably wider, the roof is supported on light steel trusses.

All windows are of steel sash construction and are of liberal dimensions and carefully placed to insure good general illumination. A number of pivotted sashes are placed in all of the windows at points near the floor and near the roof with a view to permitting unrestricted ventilation in all kinds of weather.

Ordinarily the air for cooling the motor-generator sets is taken from the outside of the building and discharged in an upward direction from the sets towards the upper ventilating windows. In the winter time it is necessary to retain this heat in the building, and the air supply is then taken from the interior of the motor-generator room so that with the upper ventilating windows closed this air may be recirculated. Inasmuch as some of these stations will be subjected to rather severe winds and low temperatures in winter, it is proposed to maintain only the ticket office or operator's room at a comfortable temperature.

The buildings are constructed without basements with the exception of a common pit under the motor-generator sets extending to the switchboard and a small pit under the main transformers. The pit under the sets acts as an air duct for the supply of air to the machines or for the location of separate blowers. It is also used to carry the direct current cables from the machines to the switchboard. The pit under the main transformers accommodates the necessary oil tanks for draining off the oil from any transformers in case of emergency, or for storing the oil while making repairs or for the storage of oil during the process of drying.

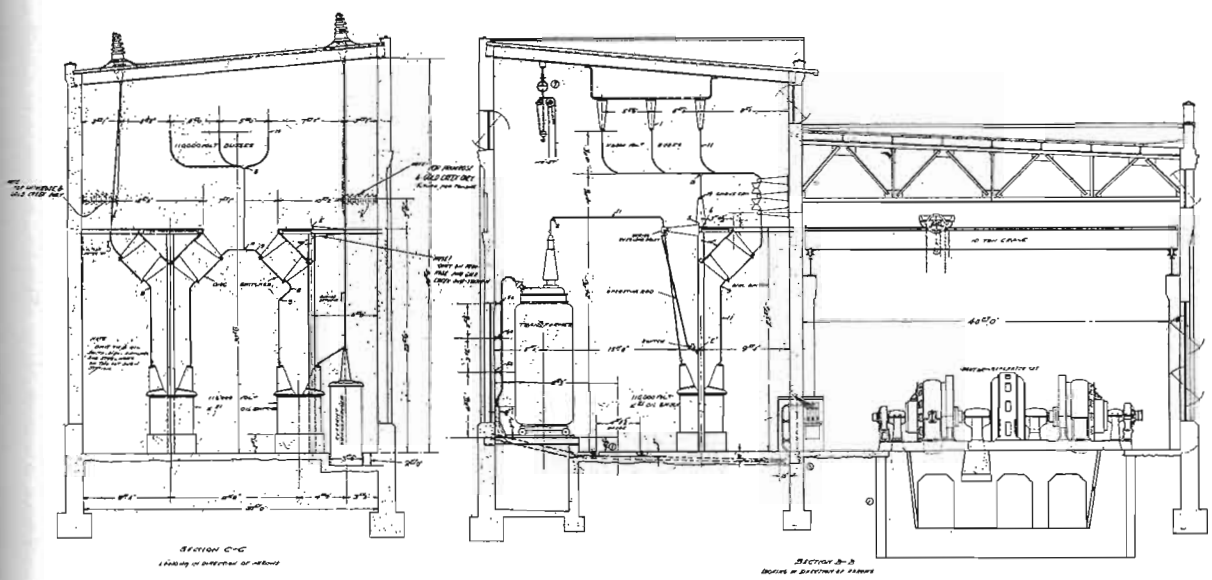

Fig. 3. Cross Sections. Two-dot Josephine, Picdmont and Morel Substation 100,000-volt Alternating Current, 3000-volt Direct Current

Convenience of Handling Apparatus

A spur track from the main line enters the motor-generator room of each substation. From this track apparatus can be unloaded from cars directly with a ten-ton hand-operated travelling crane. Another track, permanently built in the floor, together with

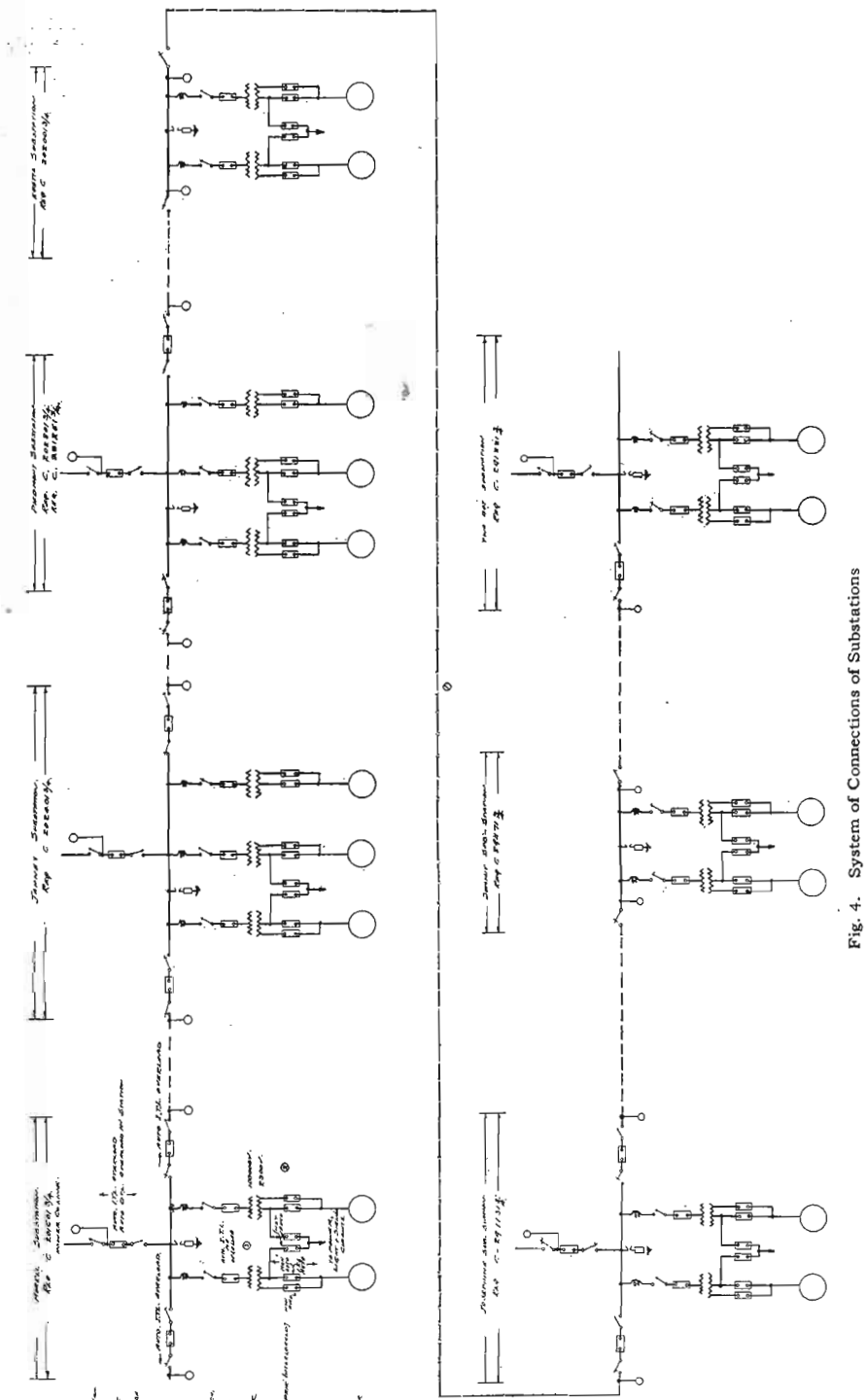

Fig. 4. System of Connections of Substations

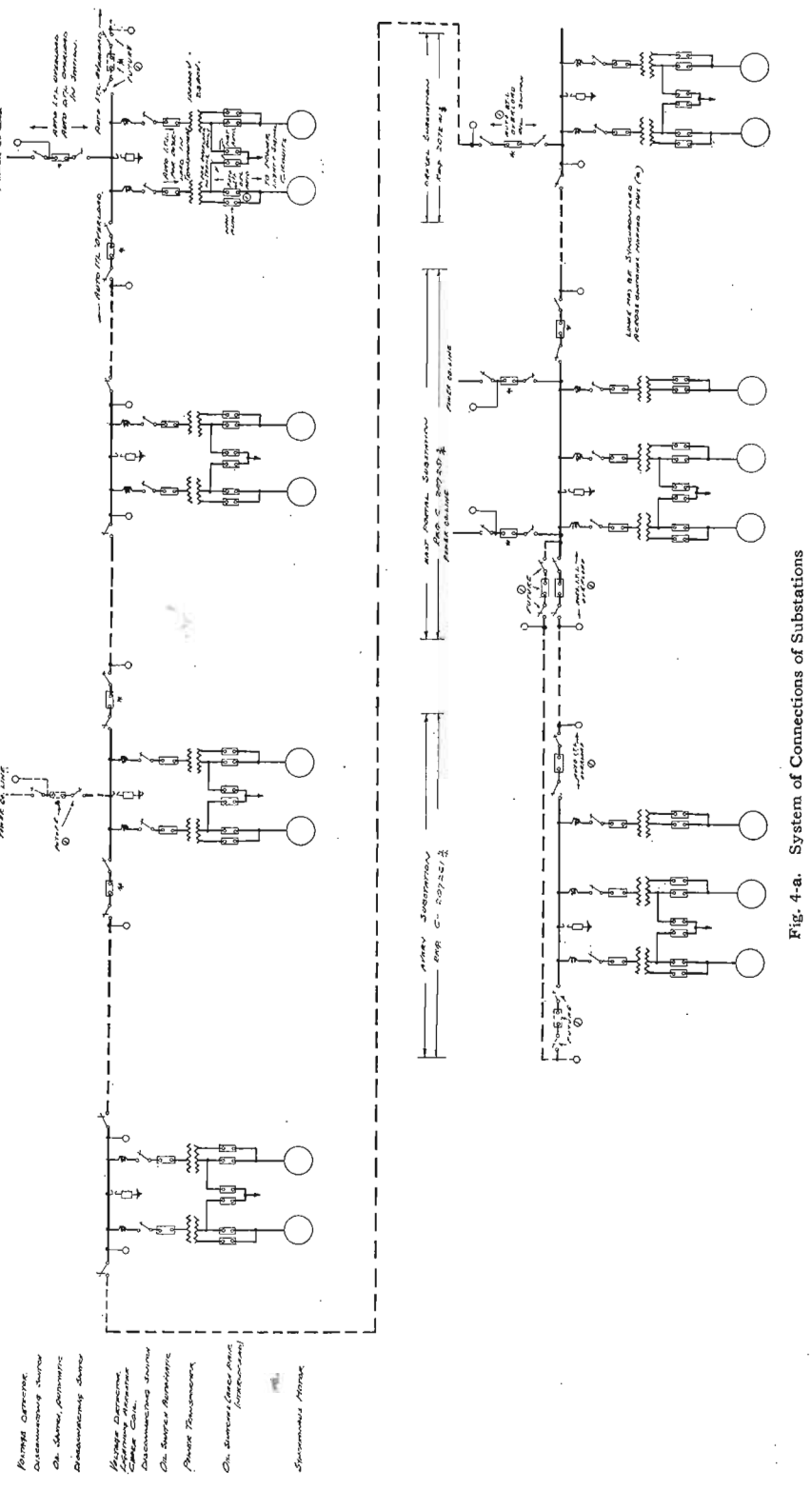

Fig. 4-a. System of Connections of Substations

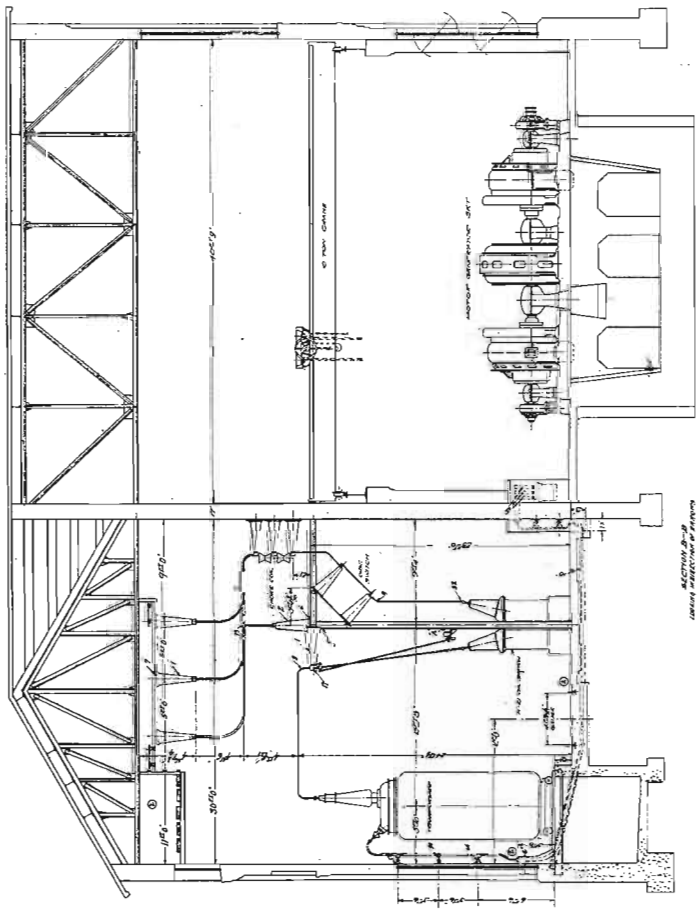

Fig. 5. East Portal Substation

a turn-table provides means of handling the transformers with a specially constructed four wheel truck.

A 5-ton chain hoist carried on an eye beam supported to the roof immediately above the transformers provides for the lifting out of any transformer core for inspection or repairs without transporting the case or removing the oil.

Wiring

Compound filled bushings are used exclusively for carrying the high tension conductors into the building. Stations constructed with flat roofs have the bushing built in the roof, but for stations employing gable roofs the same type of bushings were set in the side wall at an angle of 30 degrees from the vertical as shown in Fig. 5.

The 100,000-volt conductors inside the station consist of ¾ in. copper tubing with flush joints rigidly supported on post insulators. High tension wiring on the roof consists of solid copper wire supported on sectional rigid post insulators of the same kind as employed for the outside disconnecting switches.

As previously stated there is but one 100,000-volt lightning arrester per substation; but notwithstanding the fact that the high tension bus

and arrester tanks are inside the station while the horn-gaps are mounted on the roof the interconnecting wiring is extremely simple and free from sharp bends and inductive loops which would reduce the effectiveness of the protection they afford. The horn gaps are operated from the floor of the transformer room by means of a vertical mechanism extending down through the roof.

In Drexel, East Portal and Avery substations, which have gable roof construction, the horn-gaps have been mounted inside the building.

The 2300-volt conductors from the transformers to the motor-generator sets are non-leaded cable run in fiber conduit laid in the floor. The conduits are drained toward the pits so that water will not accumulate in them. The auxiliary 2300-volt circuits are controlled from oil switches mounted on the panels at one end of the d-c. switchboard.

The 3000-volt direct-current positive and negative cables are carried on insulators on the wall of the pit. The positive cables run directly to the generator panels while the negative cables, which are of equal lengths to insure more perfect equalization of load, are connected to a common point on the negative quick acting circuit breaker located near the ticket office.

A copper ground bus for the grounding of lightning arresters and the frames and cases of all apparatus (the motor-generators and switchboard frames are grounded for high voltage d-c. service) is carried around all sides of the transformer room and back of the main switchboard. This ground bus is connected to ten foot lengths of 1¼ in. iron pipe driven in the ground on 20 ft. centers along three sides of the station several feet outside of the building foundation.

The division of the grounds into a large number of small units facilitates the distribution of current from the ground conductor to the earth in case of a heavy lightning discharge and avoids placing absolute dependence on a single ground plate or conductor which may become disconnected by mechanical injury or corrosion. A direct path for a lightning discharge to ground is provided without passing it through apparatus ground connection or busses.

The signal feeders and 3000-volt positive feeders are carried on the wall at the back of the switchboard to one side of the building where they pass through the wall above the ticket office, Fig. 6. Aluminum cell lightning arresters enclosed in metal cases are provided for each positive generator conductor and feeder.

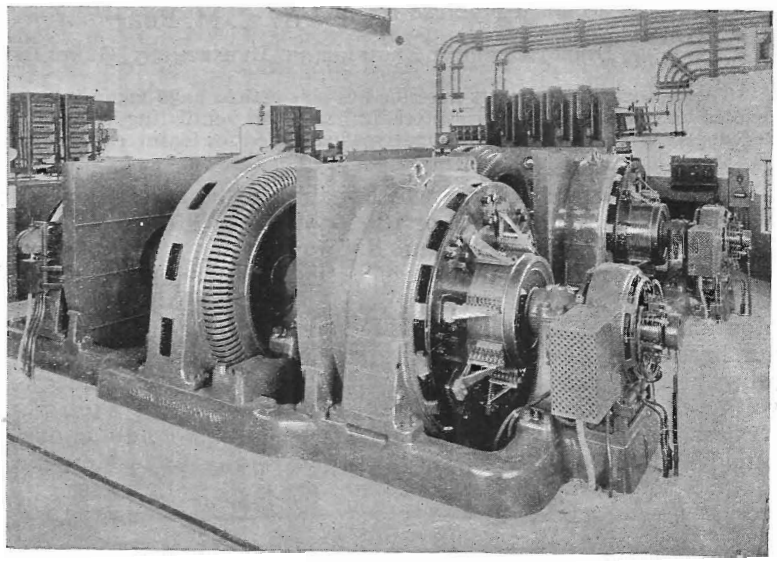

Fig. 6. Two 2000-kw., 3000-volt D-c., 2300-volt A-c. Synchronous Motor-generator Sets in Morel Substation

Operation

The small ticket office, which also serves as a waiting room, is located in the corner of the motor-generator room at the switchboard end. This room has an extended bay overlooking the track so that the operator not only has the switchboard and motor-generator sets under his direct observation but can likewise keep in touch with the train movements and perform other duties besides those pertinent only to substation operation.

The main operating aisle extends from the door of the ticket office past the main switchboard and thence between the motor-generators and the dividing wall. Along this dividing wall are located the low tension motor-generator control panels and the hand operating levers for the high tension oil switches in the transformer room.

The substations being situated in sparsely settled districts bungalows have been constructed near each station for the housing of the operators. These buildings are shown in Fig. 1.