secure a fair basis of comparison, since there is a much greater percentage of non-revenue freight with steam than with electric haulage owing to the handling of company coal for the steam locomotive.

These assumptions are based on a good quality of coal both on the locomotive and in the power station. Experience has demonstrated that there is no economy in attempting to use low-grade fuel on the locomotive, but with stationary boilers and equipment it is possible to materially reduce the cost of power by burning low-grade coal. For purposes of comparison, the ratio of 7 to 2½ is a conservative figure.

On systems where hydroelectric power can be used practically the entire coal consumption of a road may be conserved by electrification. Where steam power stations are required, nearly two-thirds of the present coal consumption may be saved.

In the table on page 862 there are 2358 miles of track which has been converted from steam to electric haulage. Figures for the kilowatt hours consumed have been tabulated and the equivalent coal calculated on the basis of 7 lb. of coal per kilowatt-hour. These figures represent the amount of coal that would be required were these electrified roads operating with steam engines. Assuming that all of this coal would be saved where water power is used, and two-thirds where electricity is produced in steam stations, the amount of coal saved is calculated in the adjoining column.

While the total track miles included in the table is less than one per cent of the steam road mileage of the United States, it should be noted that the calculated savings exceed a million and a half tons of coal or equivalent fuel oil as a result of electrical operation. The most conspicuous savings are shown by the Chicago, Milwaukee & St. Paul electrification which has secured a saving of fuel equivalent to nearly half a million tons of coal per year. The electrification of the Cascade division of this road consisting of 221 miles of track is being pushed vigorously and when in operation will also add 364,500 barrels of oil to the saving now being made.

The Operation of Railway Substations without Attendants

By W. D. Bearce

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The author gives a brief historical review of the progress made during the past three years in the equipment of automatic substations for railway service. While about thirty automatic railway substation equipments are under construction at Schenectady, the following description is mainly confined to railway systems which are now actually operating attendantless substations.—Editor.

The automatic railway substation, as it is being equipped today in rapidly increasing numbers, was first put into commercial operation about three years ago in the stations of the Elgin & Belvidere Electric Company near Chicago. After one of these stations had been tried out, the other two stations operated by this company were also equipped for automatic operation.

The operation of substations without attendants was first tried out by the Detroit Edison Company and the equipment installed in 1912 was a forerunner of the present automatic station. This installation consisted of a 500-kw. synchronous converter connected to the lighting system in the city of Detroit for the purpose of maintaining the proper voltage in the outlying districts. A new station was installed instead of additional feeder copper and was controlled by the operator of the main alternating-current supply station. Control was effected entirely from this main station over the 4400-volt, three-phase, alternating-current line. A similar installation was made in 1914 by the New South Wales Government Tramways in one of the outlying substations of Sydney, Australia. The scheme of control was quite different, however, the starting, shutting down, etc., being effected by the use of pilot wires. This station, however, was connected to a railway load and was subject to the fluctuating peaks common to railway service.

As a matter of general information, it should be stated that the stations installed at Detroit and in Sydney were of the remote control type while that put in operation on the Elgin & Belvidere system was strictly automatic. The automatic equipment is essentially different from the remote control system in that the machines are started up connected to the line and shut down without the assistance of an operator either in the station or in any remote station. These

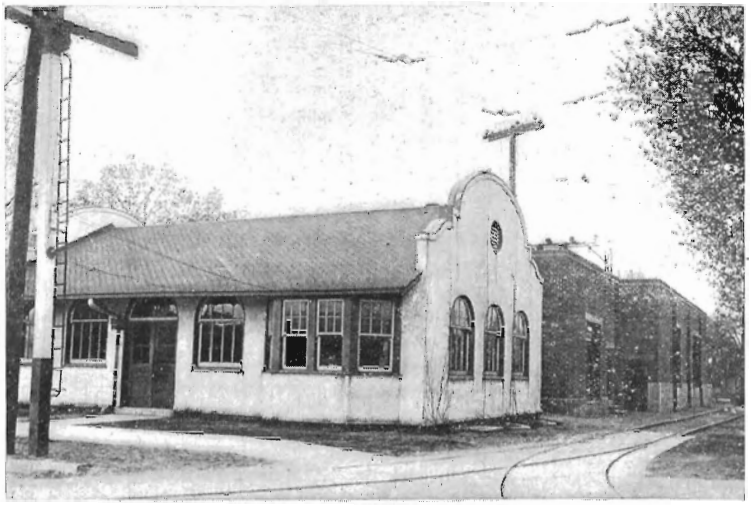

Fig. 1. Spring Lake Passenger Station, Automatic Substation and Freight House, Grand Rapids, Grand Haven and Muskegon Railway

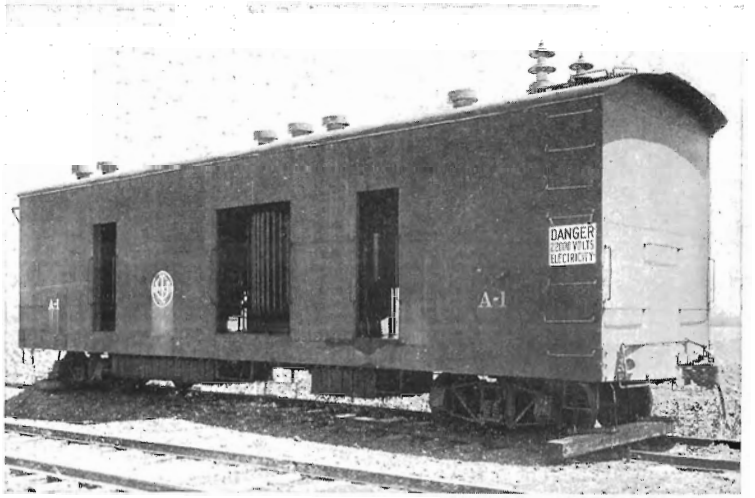

Fig. 2. Portable Substation in Operation on the Interurban Railway, Des Moines, Iowa

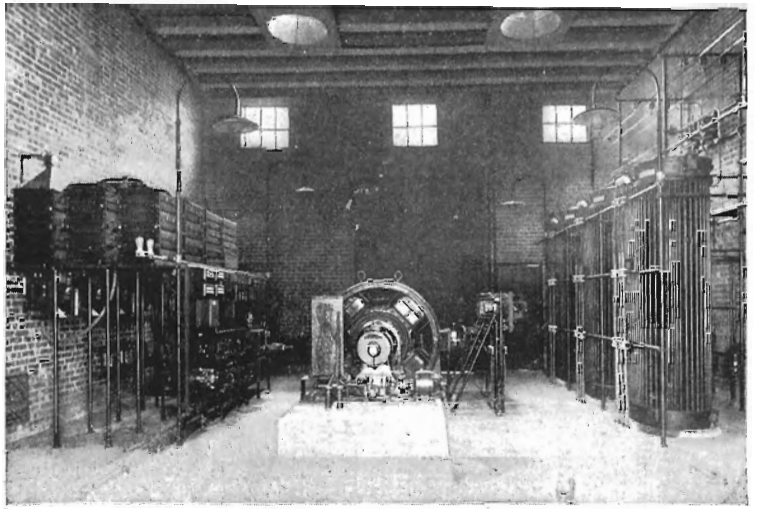

Fig. 3. Interior of the Automatic Railway Substation shown in Fig. 6

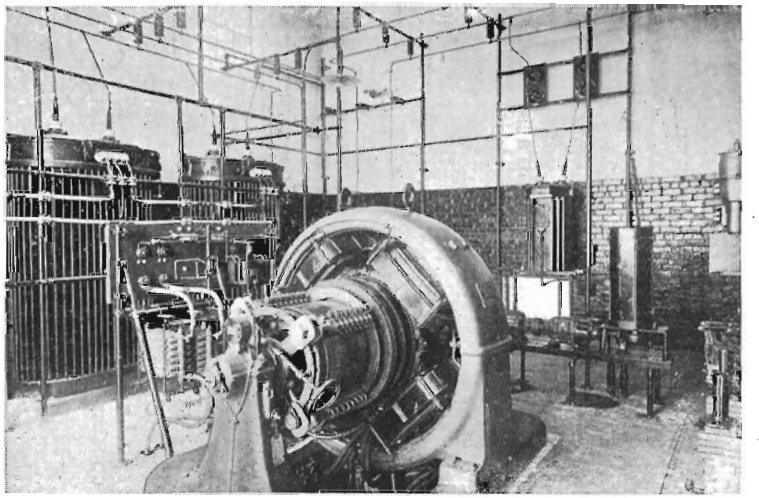

Fig. 4. Interior of the Automatic Railway Substation shown in Fig. 5

functions are performed in accordance with the requirements of the load on the system whereas with the manually operated or remote controlled station the starting, loading, and shutting down of the converting apparatus is either left to the judgment of the substation attendant or performed in accordance with a set schedule. With automatic control, sensitive relays are relied upon to observe the conditions of load on the trolley feeders and the control equipment acts automatically in response to the movement of these relays.

In order to eliminate the possibility of the circuit being opened by overload circuit-breakers, a current-limiting resistance is installed as a part of the automatic equipment. This resistance is adjusted to be connected into circuit when the current drawn from the substation machinery reaches certain predetermined overload values and the output of the station is thus limited to the desired amount. While the remote control substation makes some savings in the cost of attendants' services, the automatic station goes still further and makes appreciable savings in the cost of power. The current-limiting feature furnishes an additional safety feature which prevents injury to the substation machinery and thus assists in keeping the converter machinery always ready for service.

Fig. 5. Automatic Railway Substation (Brennan) Interurban Railway Company, Des Moines, Iowa

Fig. 6. Automatic Railway Substations (12th and High Streets), Des Moines City Railway Company

Elgin & Belvidere Electric Company

The Elgin & Belvidere Electric Company operates a single-track road 36 miles in length handling a 600-volt interurban service. Power is purchased at 26,000 volts, three-phase, 25 cycles and delivered to three substations located at Gilberts, Union, and Garden Prairie. Each of these stations contains a 300-kw., three-phase synchronous converter with the necessary transforming and switchboard equipment. The first automatic equipment was installed in the Union Station; and after a short experience, the two remaining substations were similarly equipped. Automatic operation on the last two stations was started in August, 1915.

The essential features of the installation are a motor-operated drum controller arranged to make the necessary connections for starting and connecting the synchronous converter to the line; the direct-current exciter forming a part of the same set so connected that it gives the proper polarity to the synchronous converter fields before connecting the converter to the line; the necessary controlling and protective relays; and the load limiting resistance. The converter is started up when the potential on the trolley falls to 450 volts or below. This low voltage causes a contact-making voltmeter to start up the drum controller which, in turn, energizes the actuating coils of the starting and running alternating-current switches, the field switch, and the direct-current line switch. As soon as the converter reaches full speed and full voltage, the drum controller comes to rest and the station thus operates until the current which it is supplying to the trolley circuit falls below some predetermined value, at which time a current relay operates and shuts down the station.

The series current-limiting resistors are placed between the positive terminal of the converter and the station bus, and they are automatically cut into circuit at predetermined overloads.

Fig. 3. Interior of the Automatic

The operation of these stations on the Elgin & Belvidere Electric Company's lines has been viewed by a large number of railway men and, as a result, automatic equipments have been installed and are in operation on

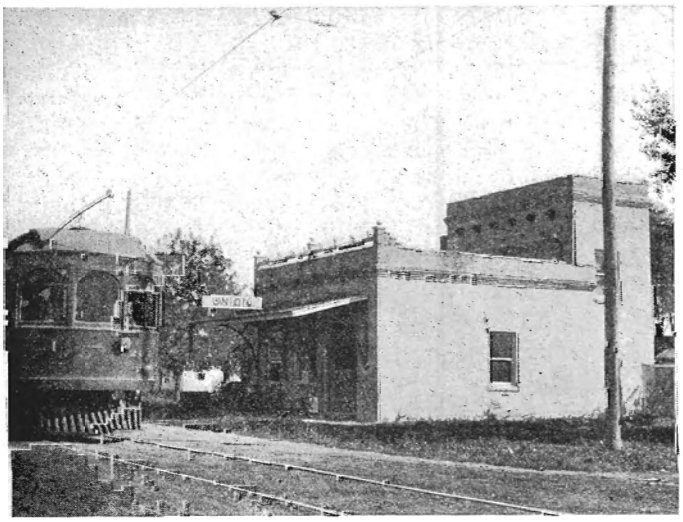

Fig. 7. Automatic Railway Substation at Union, Elgin and Belvidere Electric Company

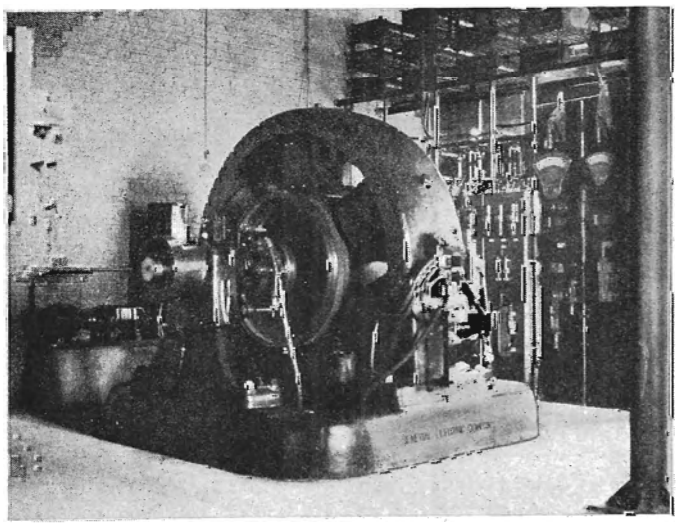

Fig. 8. Interior of Automatic Railway Substation, Elgin and Belvidere Electric Company

half a dozen other systems in the United States. There are also under construction in the Schenectady plant of the General Electric Company about thirty equipments ranging in capacity from 200 to 1500 kw.

Des Moines Railway Properties

Two of the most ardent advocates of the automatic substation are the Des Moines City Railway Company which operates 85 miles of city trackage and the Interurban Railway Company which operates 74 miles of interurban line. Both of these lines have installed a number of automatic equipments, and plans have been completed for seven additional automatic stations on the city lines and three on the interurban lines. Several more stations are under consideration. In general, the scheme of operation of these substations is the same as that employed by the Elgin & Belvidere Electric Company. One of the novel features is a portable automatic station containing a 500-kw. synchronous converter which is at present in use on a spur of track reaching out to a gravel pit. This portable substation is completely equipped for operation either on the 23,000-volt interurban transmission lines or the 4400-volt city supply. Automatic substations on the city lines are located at Twelfth and High streets, 500-kw. with a second 500-kw. unit projected; East Second and Walnut streets, 500 kw.; East Fourteenth and Lyon streets, 500 kw.; East Fourteenth and Florence streets, 500 kw.; 33rd and Easton streets, 500 kw.; Waveland, 500 kw.; and 20th and Clark streets, 500 kw.

The suburban stations are located at Brennan and Hyperion, each of 300-kw. capacity. The portable automatic substation of 500-kw. capacity is in operation between Herrold and Moran.

One of the remarkable features of the Des Moines installation was the saving effected in feeder copper by the use of automatic equipment. A detailed estimate furnished by the Railway Company shows a saving of more than $140,000 in favor of the automatic plan. Table I shows the comparative costs of the automatic and the manually operated equipment.

TABLE I

DETAILED ESTIMATE OF COST OF INSTALLING ADEQUATE DISTRIBUTION SYSTEM

Feeder Plan	
Present feeder copper at 25c. per lb.....	$112,800
Additional copper necessary for proper voltage regulation at 25c. per lb.....	172,500
Two 1000-kw. synchronous converters installed in power house, building extension, switchboard, equipment, etc..	60,000
	$345,300
Automatic Substation Plan	
Present feeder copper.....	$112,800
Seven synchronous converters and control equipment.....	98,000
Installation of seven equipments.....	8,500
Seven substation buildings.....	21,000
Seventeen miles 4400-volt transmission line	34,000
Miscellaneous material.....	10,000
Auto-transformers for stepping voltage from 2200 to 4400, labor, cable, switching equipment, etc.....	9,500
	$293,800
Credit feeder copper taken down at 20c...	90,200
	$203,600
Manually-operated substations plan, total	$345,300
Automatically-operated substation plan, total.....	203,600
Difference.....	$141,700

Although no operators have been displaced owing to the fact that all automatic substations are new, the Des Moines lines are making a large saving on operators' wages since the several automatic stations dispense with attendance which would have been required for manually operated stations. Considerable savings are also being made from the elimination of light-load losses as well as the reduced maintenance on the equipment and the lighter duty secured by the load-limiting resistance.

Milwaukee Electric Railway & Light Company

The first 1200-volt automatic substation was put in operation during last summer on the Interurban division of the Milwaukee Electric Railway & Light Company's lines at East Troy. This substation is at the end of the interurban division 28 miles distant f om West Allis, the nearest substation, and contains four 300-kw., 25-cycle, 600-volt synchronous converters arranged to be operated two in series for 1200 volts. One set of these machines has been equipped with automatic control and is now handling the load without assistance. The other set is being retained for standby use. Some modification of the equipment used in former stations was necessary, in order to take care of the 1200-volt service and to provide for the operation of the two machines in series. The equipment is arranged to cut in the two machines when the trolley voltage drops to 950 and the current relay operates to shut down the station when the current falls to 25 amperes. The dashpot effect is used to prevent the station from dropping out during the ordinary passenger stop which requires about five minutes after the power drops to the 25-ampere point. Since there is a two-hour schedule on this division, the station is shut down quite a large part of the time. Estimates on the approximate saving effected by the elimination of two operators and the reduction in the no-load and light-load losses give an annual saving of more than $1700 per year for the single station.

Grand Rapids, Grand Haven & Muskegon Railway

Another station recently put in operation is the Spring Lake Station of the Grand Rapids, Grand Haven & Muskegon Railway Company containing a 500-kw., six-phase, 600-volt synchronous converter. This is a new station and was put in operation with automatic equipment in May, 1917. The line is equipped for the most part with an over-running third-rail, and handles considerable freight and express service in addition to the regular passenger and summer resort traffic. The automatic equipment is similar in general to the other 600-volt stations now in operation; and it is expected that considerable savings will be effected from the elimination of operators' wages and light-load losses on the machine.

Other automatic equipments are in operation in different parts of the country and among the several stations now under construction is one automatically controlling two units in the same station, the second unit being put in service to take care of load peaks during rush hours at morning and night while the first unit handles normal loads.