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PIONEER ELECTRIC RAILWAY WORK OF THE WESTINGHOUSE COMPANY
results was made evident in an alteration of the plans of the Metropolitan System so that electricity was adopted and the contract for steam locomotives was cancelled. The next result was the design and construction of the North Western Elevated Railway of Chicago. This was the first elevated railroad to be designed exclusively for electric traction, except the Illinois electric railroad which was the first to adopt electric traction after the Intramural road, although it was the Liverpool Overhead road in England. Intramural road was the first electric railroad to be constructed in the United States.

Soon after this, the use of electric locomotives was abandoned on the South Side Elevated Railroad, of Chicago, and electricity was adopted. The Lake Street Elevated, soon followed, and in the course of a few years the Manhattan Elevated, of New York, was equipped. To-day the entire elevated railroad systems of this country and of Europe are equipped with electric drives, and I believe it is fair to claim that the Intramural Railroad, at Chicago, was the chief element which led to this result.

PIONEER ELECTRIC RAILWAY WORK OF THE WESTINGHOUSE COMPANY

By R. C. Lamme

The Westinghouse Company took up the development of electric railway apparatus in 1885, although it did not put apparatus on the market until the early part of 1886. The persons who were particularly interested in the development of this early work were George Westinghouse, Albert Schmid, Philip Lange, Oliver B. Shallenberger, H. P. Davis, N. W. Storer, and the writer. Albert Schmid was superintendent of the Westinghouse Works, then at Garrison Avenue, Pittsburg, and he was intimately in touch with the general designs of the apparatus, particularly the mechanical features. Philip Lange, during the early development, was superintendent of the detail department, and was directly interested in the controllers, switching appliances, and other details. Mr. Shallenberger was the electrician of the company, and as such was more or less interested in the work, but Mr. Shallenberger's duties were primarily in the direction of alternating-current apparatus, and he did not have any direct contact with the development of the railway apparatus as other engineers. H. P. Davis became actively interested in this work in the early part of 1881, working in conjunction with Mr. Lange in the detail department. Mr. Storer did not become actively engaged in this work until about 1882 or 1883, although he was in close touch with it previous to this, in the testing room. The writer was actively engaged in the early development of the work from the start.

In the latter part of 1889, Albert Schmid informed me that the Westinghouse Company was planning to take up actively the manufacture of a direct-current railway system, and he instructed me to immediately begin the study of the various systems and apparatus already on the market, especially the railway motor itself. He told me that I should be prepared to furnish electrical data for a suitable railway motor as soon as any definite instructions were given out that a line of apparatus was to be built. These instructions were carried out, and as the entire line of work was new to the company, I necessarily came in touch with the detail work as well as with the motor itself. The electrical designs of the various early motors were prepared by me under Mr. Schmid's instruction, and, as indicated above, the characteristic mechanical features of the designs were furnished by Mr. Schmid. E. C. Means, at that time chief draughtsman of the company, also assisted Mr. Schmid in the general features of the design.

Successful commercial operation, Mr. Emmet severed his connection with the Westinghouse Company.

A great number of other engineers have been more or less interested in the development of the Westinghouse railway system, particularly in later work. It may be of interest to note that most of the above-mentioned engineers are still in the employ of the Westinghouse interests and in close touch with modern developments in this line of work.

Taking up the development of the motor in the proper order, it should be noted that in 1889 the Westinghouse Company did some work on adaptation of the Tesla motor to street car work. This work was experimental and never reached the stage of true commercial test. The motors were of the Tesla motor then being built, with polar primaries and distributed short-circuited secondaries. Such motors, of course, did not have suitable characteristics for traction service. This line of work was abandoned, and a short time afterward the development of the direct-current system was actively taken up.

As stated before, in the latter part of 1889 the company planned to get out a direct-current system. This work was pushed through rapidly, and early in 1890 a direct-current railway system was completed for shop tests, and the first motors were put in service on July 3 of that year, on the Pleasant Valley line in Pittsburg. The motor was a two-pole machine, with cast-iron field and surface-wound armature, like all practical motors at that time. The field was wound with two sets of coils, and speed regulation was obtained by the sectional field method in which two coils were in series for lowest speed, and
one coil was short-circuited for increased speed. About 300 of these motors were put on the market.

The control system used with these motors was straight rheostatic, except the short-circuiting of one field winding for higher speed. The armatures were connected permanently in parallel, and the field windings of the different motors on the car were in parallel. No attempt was made to equalize the armatures, as there was apparently but little unbalancing in these machines, probably due to the very large air gaps.

These early motors had the gears enclosed in cases. The motor was double reduction. The general type of this motor was very similar to that of the other systems in commercial operation at the same time.

The controller consisted of a wooden drum with metal strips on the outside. The general appearance was similar to the Sprague controller, but the steps were principally for rheostatic control instead of commutated fields.

The rheostats put out with these early motors are worthy of mention. These rheostats were peculiar in the fact that they were made of copper wire instead of high resistance material. Three coils were used. Each coil was made in the form of a thin cylinder. The three coils were of different sizes, so that they could be assembled in concentric form with air spaces between. The reason for adopting this design was that

The following features were used in these early motors:

1. The motor had four poles.
2. The poles were radial.
3. Poles were placed at an angle of 45 degees from the horizontal or vertical.
4. The poles were placed inside the yoke and were entirely surrounded by the yoke.
5. The yoke also extended over the projecting end of the field coils, thus protecting them from injury.
6. There was one field coil on each pole.
7. The coils were wound without shells or bobbins and were insulated after being wound.
8. The field frame served to enclose the motor. (The No. 3 motor was not entirely enclosed, but there were end covers on the lower half of the machine.)
9. The poles were very highly saturated at the face, thus reducing the cross induction and preventing change in lead.
10. The armature was slotted.
11. The slots were open.
12. The core was drum wound.
13. The coils were machine wound.
14. The present well-known two-circuit or series type of winding was used, allowing two brush arms on a four-pole machine without cross connections on the winding or commutator. The two brush arms were on the upper side of the commutator.

The following features have since been adopted in street railway motors:

1. Entirely enclosed frame.
2. Laminated poles.
4. Pole faces partly cut away to obtain saturation and to prevent cross induction.
5. Bearings carried by the field frame instead of by a separate surrounding frame.
6. Also improvements in shape of armature coils, ventilation of armature core, etc.

It will thus be seen that the number of features embodied in the No. 3 motor, which has been adopted in modern practice, was very great compared with the number of features which has since been added in railway motors.

The control system on these early No. 3 motors was practically the same as used with the No. 1 and No. 2. These No. 3 motors, like the No. 1 and No. 2, had cast-iron field frames and poles. The motors were rather heavy for their output, although the weight per horse-power was about the same as for the No. 1. The amount of material which was idle electrically or magnetically on the No. 3 motor was rather small compared with the amount of such material in the No. 1 and No. 2.

After the No. 3 motor had been developed sufficiently to show that it was a commercial machine, a design for a gearless motor was taken up. The first gearless motor put out was called the No. 4. It was also a cast-iron machine and was rela-
Street Railway Journal [Vol. XXIV. No. 15.

544

Reduction very heavy. The speed of the 25-hp No. 4 motor was about 200 revolutions at normal load.

This No. 4 motor was an enclosed motor and had four poles, salient and two consequent. The armature was directly on the car axle, and the field frame also had its bearings directly on the car axle.

A small number of these motors was built and given the test of commercial service. Some of them were operated for a year or so. The motors operated well enough, but were too heavy to be commercial. Track constructions in those days

No. 12A MOTOR

were very inferior to present practice, and the motors, in addition to being rigidly mounted on the axle, were very much heavier per horse-power than modern motors.

On account of the great weight of the No. 4 gearless motor, the No. 2 was called the No. 3. It was about the same capacity as the No. 4, but was about two-thirds the weight. The frame was of cast iron, practically enclosing the machine. There were four salient poles and two consequent, the latter being at the top and bottom. A few of these motors were built and given the test of commercial service, but experience had shown that the gearless motor was not a suitable one for street railway service, due principally to mechanical considerations. Therefore, no further attempts were made to develop the gearless motor for ordinary light traction service.

The No. 3 motor was made in three ratings, viz.: 20 hp, 25 hp, and 30 hp. The general construction of these three motors was the same, the difference being principally in the amount of copper in the armature and field windings. There was also a demand for a motor of somewhat greater capacity, and a 40-hp design was gotten out. This was a rather special motor, and but few were sold.

After the No. 3 had been in the market for some time and had proven a great success, there was a demand for a motor of similar capacity and electrical features, but of considerably smaller dimensions. In 1893 a new motor was designed which contained many of the principal features of the No. 3 motor, but was of much less weight and somewhat different construction of frame. This was called the No. 12 motor. A later modification of this was called the 12-A. The No. 12 was a cast-iron machine, like the No. 3, but was without the surrounding frame, the bearings being carried by the field frame of the motor itself. The motor was practically enclosed, like modern motors. The armature contained about half as many slots as the No. 3 armature, and there were two coils side by side per slot. Otherwise the motor was very similar to the No. 3. This motor and its successor, the No. 12-A, were made in three ratings, viz.: 25 hp, 30 hp, standard speed, and 30 hp, slow speed. The 12-A motor contained almost all the prominent features of the present types of railway motors, the principal

difference being that it had cast-iron poles and yokes, while present designs of motors have steel yokes with laminated poles.

The next important motor gotten out by the Westinghouse Company for street railway service was called the No. 38. This motor, with its modifications, the 38-A and 38-B, contained some departures from the 12-A in the use of cast-steel field steel with laminated poles cast in, and an armature winding with three coils per slot instead of two or one. This motor was de

No. 12A ARMATURE

veloped in 1894. It can be considered the pioneer of the present

model of the motor, with cast-steel poles and laminated poles, and it was put on the market in the spring of 1895.

A somewhat later motor, built on lines similar to the No. 38, was the No. 49, rated at 35 hp. This motor had steel yoke with laminated poles cast in.

In later motors for street railway service gotten out by the Westinghouse Company, the bolted-in pole construction has been adopted instead of the cast-in poles, and many other features have been more fully developed.

The above gives a general description of the various types of motors gotten out up until about 1897, and covers only those which were given commercial tests. A number of experimental motors were built, especially about 1890-91, which were never put upon the market, and in some cases were simply built for obtaining certain data.

About the time that the No. 1 motor was gotten out, some tests were made on driving street cars by means of friction wheels. A motor was built and placed upon a truck in the shop, for making such tests. This motor was of the consequent-pole type, similar to the well-known Weston type of machine, with four field coils and two consequent poles. The armature was geared to a countershaft, and to the countershaft was attached two friction rollers or wheels, which bore down upon the car wheels, each roller lying between two car wheels. This

NO. 12 A ARMATURE

construction was given certain shop tests, but was found to be rather inflexible and was very noisy. It was decided that it would not be a suitable article for commercial service, and was therefore not given the outside tests.

A series of tests was also made on the use of magnetic gearing. Grooved wheels were used, the grooves being in the shape of V's. By means of magnetizing coils on the axles or shafts a magnetic field was set up between these driving gears. Tests were made to determine the power that could be transmitted by this device, but it was found that it would be insufficient for the torque which would be necessary for street car service.

A considerable number of experiments were made with different methods of street car regulation, such as commutated fields, sectional field coils, etc. A series of tests was made with commutated fields, three field coils being used in somewhat the same manner as the Sprague system. This system of regu-
laction was found to be unsuitable with the Westinghouse No. 1 and No. 2 motors, due principally to the fact that commutated field control is not satisfactory except where the field inductions can be worked over a relatively wide range. No. 1 and No. 2 motors being of cast iron, it was found that there was not any particular advantage in using the commutated field method of control. There was found to be a slight advantage in the use of the sectional field method with two field coils, one being large and the other comparatively small. These two coils were in series for starting and for lower speeds, but for higher speeds the smaller coil was short-circuited. Tests were also made with the sectional field method with several coils, all being in series at start and short-circuited successively for higher speeds.

With the No. 3 motor straight rheostatic control was used, previous to the introduction of series-parallel control, as it was considered that the sectional field method did not present sufficient advantage to compensate for the extra complication of eight field coils instead of four.

Some mention has already been made of the rheostats and controllers used with the early system. All the early commercial controllers were of the drum type and were placed on the car platform. As stated before, the first controller was straight rheostatic, with one notch for short-circuiting one field coil. Several variations in constructional features of this controller were gotten out and put on the market.

In 1891-2 considerable work was done in the direction of using series-parallel connection of the motors, for determining whether speed control in this manner was feasible. This work was carried out in connection with the No. 3 motors. In the early part of 1892 a series of tests was made, both in the shop and in service, with a pair of these controllers, and shortly afterward this method of control was put on the market by the Westinghouse Company. The series-parallel method of control soon became so thoroughly established that it was practically the only street car control manufactured by the company. There have been many modifications and improvements in the series-parallel controller since first brought out by the company, among them the addition of the magnetic blow-out, but the drum construction placed on the platform has been retained, except for very large equipments.

 Mention has already been made of the first rheostat made by the Westinghouse Company for street car work, this consisting of concentric copper coils. This was soon superseded by a rheostat made of iron wire spirals in a supporting frame and covered with a heavy wire netting with a rather large mesh. This rheostat, on account of its appearance, was named the "bird-cage" type. The use of this rheostat was continued for a considerable period, but was then superseded by a rheostat made of iron strap wound in spirals on supporting shells. A number of these spirals were assembled together in one frame. This was a more substantial rheostat than the "bird-cage" type, and was soon used almost exclusively. The adoption of the series-parallel control reduced the size of rheostats required, and thus to a certain extent simplified the problem of its construction.

One difficulty found with the early No. 3 motors was in unbalanced armature currents with two or more motors per car. The armatures of these motors were connected in parallel and the field coils were also paralleled, instead of each armature being connected in series with its own field. It was therefore found necessary to equalize the motors by adjusting the air gaps. This was done by putting sheet-metal strips between the two halves of the yoke. Two ammeters were connected in the armature circuits, and the fields were adjusted until both ammeters averaged the same over the working range of the current. This arrangement was later abandoned in favor of the present connection, by which each armature is in series with its own field, thus automatically producing the required balancing action.

One of the most serious difficulties which developed in the early street railway service was in connection with the mica on the No. 3 motors. The first few motors had mica about 1-32 in. thick between bars. In those days the mica was not split and then built up, as in present practice, but was generally punched out of solid pieces and was extremely hard. This 1-32-in. mica appeared to work in a very satisfactory manner, but as it was thinner than the usual practice on the No. 1 and No. 2 motors, about 1-16-in. thickness was then adopted for the No. 3 motors. Practice soon showed that this mica would not wear satisfactorily and there was continued trouble due to it. It was soon determined that if the mica was cut down below the surface of the copper the motor would work satisfactorily until the copper wore down to the level of the mica. This showed conclusively that the trouble was with the mica. We then went back to the 1-32-in. mica, and had very little trouble, particularly as we had begun to build up the mica of thin sheets, somewhat like present practice. It is interesting to note this early experience in cutting the mica below the copper, in view of similar practice in some modern large motors. It has been announced as a great discovery that cutting the mica below the copper was a great improvement in large street car motors. In fact, it is an improvement if the mica in such motors is giving trouble due to lack of proper wearing qualities, but the purpose of cutting down the mica on these late motors is to accomplish the same results as in this early experience above cited.

In 1892 two single-phase motors of about 10 hp were built by the Westinghouse Company for determining the possibilities of using alternating current for traction work. These motors were designed for 2000 alternations per minute and about 200 volts. They were of the series type, with commutators, and had a relatively large number of poles. These were placed upon a car and tested on a short piece of track with some very short curves and rather steep grades. Tests showed that the motors were not powerful enough to operate the car on the
curves and grades, also the track was very poorly built and not properly bonded, and the voltage drop in the rails was excessive. A very small generator was used for these tests, and its capacity was insufficient for the service. On the car a transformer served to transform from about 300 volts on the trolley to that required for the motors. There were several taps on the transformer, and by means of several single-pole switches the voltage could be varied to the motors.

There did not appear to be sufficient field for such a system and it was decided not to undertake any larger motors. It was considered at that time that such a system would be ideal for locomotive work, but as there were no such projects in view then, no work was done in building large motors of this type.

By the early part of 1895 the problem of the use of polyphase motors for traction service was taken up and a pair of such motors were built and tested at the East Pittsburgh works. These motors were built for 25 cycles and of a nominal capacity of 25 hp each. The primaries and secondaries were wound for 500 volts, and the winding of the rotating part was connected through three collector rings. These motors were designed to be used with both rheostatic and with tandem-parallel control, and shop tests were made with both methods of speed control. With the tandem connection half speed was obtained by connecting the secondary of one motor to the primary of the other in the now well-known manner. The results obtained with these motors on shop tests indicated that they could not compete with the standard direct-current systems as regards performance, etc., besides requiring the complication of two trolleys.

Two 100-hp polyphase motors were also designated in the latter part of 1895, and were built and given shop tests on a short track just outside the East Pittsburgh shop. These motors were started and regulated by means of variation of the voltage supplied, such variation being obtained by means of a two-phase induction controller. It was also found that this system would not compare favorably in economy with the direct-current system, and after a series of tests it was abandoned.

Among other experiments with these 100-hp motors, they were wound for two numbers of poles, so that they could be run efficiently either at full speed or at half speed. This was found to be more economical than the single-speed equipment, but yet did not compare favorably with the direct-current system.

These polyphase motors also were tried with variable-speed gears of various kinds, but were not found satisfactory.

Since 1896 the development of the electric traction motors by the Westinghouse Company has been along fairly well established lines, except in the single-phase system, which the company has lately put upon the market. Some polyphase-motor equipments have been built and installed for haulage of canal boats on the Miami & Erie Canal. This has been about the only radical departure from standard direct-current systems which the company has had in commercial service for any long-continued period.

"We are impressed at once with the national importance of the street railway interests, and this feeling grows deeper and broader as we consider the financial relations of our calling with the millions involved; the varied, useful and indispensable relations it sustains to the well-being of every person in every city and every town of any importance in the whole land; the mighty factor it has become in making or unmaking values in properties of all kinds; and especially does this feeling become almost overwhelming when we consider to what grand proportions this industry has grown during a lifetime of the youngest of our members."—From Washington Meeting, 1888.