

DISCUSSION ON "THE NEW HAVEN SYSTEM OF SINGLE-PHASE DISTRIBUTION, WITH SPECIAL REFERENCE TO SECTIONALIZATION." NEW YORK, JANUARY 10, 1908.

W. S. Murray: A retrospect always reveals more than a forecast. A perusal of the paper indicates to me, as doubtless to you all, that what has been touched upon is only a small percentage of the interesting and valuable data that could have been included were it at the election of the author to give his undivided attention to the subject.

I shall not attempt to apologize for what the paper lacks, and can simply say that odd moments, particularly those occurring while riding on the trains of the railroad company, supplied the time during which the article was written.

There has been no attempt to go into either the electrical or mechanical specifications of the distribution system. These were all included in the several contracts existing between the railroad company and the manufacturers and contractors, the general outline of which covers all points bearing upon the physical performance of the material furnished. As far as it was possible to anticipate, various weather conditions were considered in the design of all parts subject to changes of temperature, to wind, and to ice formation. We have passed through several snow, ice, and wind storms, and combinations of these, and all the iron structures, messenger, trolley, and feeder wires, have satisfactorily demonstrated the factors of safety which were included in their design.

A description of the electrical and mechanical details of the distributing system of the New Haven road has appeared in the columns of the engineering papers. My aim to-night has been more to acquaint you with some of our experiences rather than our theories. Therefore, fully conscious of many glittering omissions germane to the subject, and counting on the discussion to bring them out, I shall read the paper. [Here Mr. Murray read his paper.]

The discussion of double or single catenary construction on main-line electrification was intentionally omitted from the paper. A choice of the one or the other must be a compromise of a great many considerations, the principal ones being the number of tracks to be electrified, and local conditions; but there is one fact that has been conclusively demonstrated to me, namely, either the trolley wire or the trolley shoe must be flexible, whether the construction be for main or for branch lines. Of course in the single catenary construction a flexible contact conductor is provided. In the triangular construction, the contact conductor is rigid. This requires a flexible shoe, which in a degree is secured by the spring pantagraph arrangement. Experience, however, has forced upon me the conclusion that the pantagraph must be still further supplemented by a light but strong mechanism which will insure flexible contact between the

shoe and trolley wire, thus not offering a great deal of inertia in movement when the shoe meets the hard spots of the line which exists at the catenary hanger points.

A form of construction we have adopted in our East Port-Chester yard, in which the latitudinal catenaries are supported by cross-catenaries—in some cases spanning as many as ten tracks—has about it a great many attractive features, and I am not too sure that experience will not bring out the possibility of using the cross-catenary for main line work. Such an arrangement, if more frequently reinforced with cross-bridge anchorages such as now used in the New Haven electrification, will bring a lighter and cheaper construction, and possibly afford a greater opportunity in insulating the overhead system from ground. I can see no reason why single catenary spans need be made any less than those used in the double catenary construction, as the cross-rigidity that may be desired can be obtained by tying into adjacent latitudinal catenaries, all of which, of course, are subject to the pull-off construction at present employed. Of course there are a great many pros and cons about this, and again we are forced to the conclusion that to-day is not the time for standardization, as it will pay not to accelerate our conclusions at a greater rate than the operating evidence upon which they should be based.

Still another point that has not been touched upon in the paper, is the great flexibility offered in the double-switch arrangement of supplying power to a trolley wire at the two extremities of its section. It is readily seen that if trouble exists in one of the circuit-breakers supplying a trolley wire in any given section, this switch can be immediately cut out and all the power supplied from the remaining switch at the other end. This flexibility, of course, is secured in virtue of the low loss due to high-tension transmission, and the employment of by-passes or feeders, to which previous reference has been made.

An impression has come to me that I might have dwelt more fully on the details of the system of distribution. As stated previously, it has been so universally described in the engineering papers that I have felt as if I were writing about results and experiences with something the general parts of which we were all acquainted. If I have universal support in this impression, I can only offer in amelioration, Diagram (4), which assembles all the links of our transmission chain, the functions of any one link of which are common knowledge.

L. B. Stillwell: I have not found time to read Mr. Murray's paper carefully, and I do not propose to criticize the sectionalization of the New Haven and Hartford trolley or its feeder layout. I have a very high opinion of the importance of these parts of the plant, which unquestionably are too often neglected. There are cases where very large investments have been made to insure continuity of service in which, judging by results, the investment has not been made in the right place. Instances might

be mentioned in which, at great expense, excess generating capacity has been installed adequate to take care of the service, even in case of destruction of 50 per cent. of the total generating plant, and yet when the feeder layout was under consideration oversights apparently have occurred as the result of which very severe interruptions of service have followed. Unquestionably, therefore, criticism of the organization of supply circuits for large distributing plants, particularly for railway service, is highly beneficial. I say particularly in railway service, because in industrial power service the interruption of a feeder now ordinarily involves only a local and a very temporary failure of service; whereas in railway operation if we stop trains on one part of the line we are liable to hold up the entire operation of the railway.

W. B. Potter: The ordinary 600-volt trolley line is of little value as a standard with which to compare the 11,000-volt catenary under steam railroad conditions. Considered as an example of good construction, I have never seen the equal of the catenary to which Mr. Murray refers. As to the relative reliability and maintenance of such an overhead high-voltage trolley compared with a 600-volt third-rail, under conditions necessitating joint operation with steam, I believe this to be a debatable question.

I agree with Mr. Murray as to the desirability of a through feeder in parallel with the different sections; I do not see the need, however, of two such feeders on the same phase as the trolley wires. For local power the combination of the single feeder with the trolley wires would seem sufficient reserve. If any accident involved all four of the trolley wires, it would probably include the feeder as well; in case it did not, a single feeder could supply power beyond the break.

As to the length of the main-line sections, I favor from three to five miles, rather than less; as this question affects the reliability of operation, it seems that a reduction in the number of switching appliances would be favorable. Five-mile sections have proved satisfactory in third-rail operation, and there appears to be no reason for shorter sections with the high-voltage trolley, unless it is the greater liability of the longer sections to break down. It seems desirable, however, that at track cross-overs there should be a short section controlling the main-line and cross-over tracks, the better to insure cross-over movements in the event of interruption on the main-line sections.

Twenty-two feet seems to be a generally recognized standard height of trolley wire. It is unfortunate that this height cannot be maintained throughout, as it would then be possible to use a much lighter form of pantagraph. Overhead bridges, with their limited clearances, often necessitate a vertical movement of the collector of from seven to eight feet, and this condition requires a pantagraph structure more liable to derangement.

Depreciation of the catenary insulation from steam loco-

tive smoke would naturally be expected, and the extent of trouble from this cause seems to have a bearing on the permissible trolley voltage. Conditions might well arise where either copper or efficiency would have to be sacrificed for reliability.

The suggestions with regard to time-relays and switch indication are in line with well established practice. As to the method of operating the circuit-breakers, I understand that they are at present controlled from the main power circuit. Should not some means be provided for operating these switches in the event of failure of power? As these circuit-breakers are near signal towers, where manual operation could be conveniently applied, would not this be the more reliable method? Lever connections would provide certainty of operation and would not interfere with the automatic tripping. The proposed change from the bridges to switch houses would simplify the mechanical connections.

There is no doubt as to the desirability of guarding against the spanning of two trolley sections, as there is always the possibility of one section being grounded. Such accidents will occur. If the two pantagraphs or trolleys are far enough apart to span the section insulators, the only safeguard seems to be a fuse located between the two collectors.

O. S. Lyford, Jr.: Mr Murray's paper is written from the point of view of operation of a multiple-track road: when viewed from the standpoint of single-track operation, this subject has some rather different aspects. For instance, Mr. Murray says:

1. In one-, two-, three-, or four-track railroads, the single-phase distribution should include, besides the trolley wires, by-passes or feeders.

I do not take exception to this statement as relating to two-, three-, or four-track roads, but it does not necessarily apply to single-track roads. The objects of sectionalization are three: first, to minimize the interference with the operation of the road in case of line trouble; secondly, to locate the fault quickly; and thirdly, to reach the fault with a work train.

As to the first object, to minimize the interference with operation, I think it is quite apparent that a parallel feeder is not of much use as a by-pass in a single-track road of moderate length. Take, for illustration, the Erie road south from Rochester, Fig. 1. This is a single-track road, running from Rochester to Mount Morris. Power from Niagara Falls is received at a sub-station at Avon. At present the lines north and south from Avon are operated as two legs of a three-phase system, the common point being connected to the track. Avon is a junction-point with an east and west line of the same road. Rochester is about nineteen miles from Avon, and Avon is about fifteen miles from Mt. Morris. With a schedule speed of about twenty-four miles an hour and hourly service in each direction, it is apparent that a dead point anywhere on the line will, in a few minutes, block all trains on one side of the junction. The ability to move trains up to the dead point will not materially help the service.

The Erie line is divided into sections, but the principal object of sectionalization is to locate the fault quickly. The section breakers are "jumped" through hand-operated switches and are placed near passenger stations or signal towers. If there is trouble, the system operator, by telephone orders, can have the section switches opened in sequence and quickly locate the section on which the trouble occurs. Mr. Murray speaks of special apparatus being developed to test for faults and locate them quickly. If such apparatus be produced, it will probably be more convenient than the use of section switches.

Considering the third object—to reach the fault with a work train—even with short sections such as have been discussed to-night, the work train, if operated by trolley, could not get within three-quarters of a mile or so of the fault, and it would be impracticable for the men to have to go the rest of the way on foot to make the repairs. The logical conclusion, therefore, is that the work train should be operated by an independent unit, either a steam locomotive or a gasoline car, preferably the latter, because it is more easily put in service.

Independent operation of long sections between important points is desirable. Usually, however, this will be best accomplished by high-tension feeders, rather than by by-pass feeders operated at the trolley voltage. The Erie system has been planned so that if the electrification is extended beyond the limit for economical transmission at 11,000 volts (for instance from Mt. Morris to Dansville) the present transformers may be connected so as to obtain either 11,000 or 22,000 volts, and 22,000-volt feeders may be carried to the distant section, serving the trolley wire through autotransformers. This plan allows transmission at double voltage and saves copper without appreciable complication.

Another case may serve to illustrate the conditions which arise in single-phase operation. The Denver & Interurban Railroad line from Denver to Boulder has a single-track main line and two single-track branches (see Fig. 2.) The powerhouse is about 2 miles from the Louisville branch and 5.2 miles from the junction point. Power is supplied over two feeders from 11,000-volt, single-phase generators to the junction point. The length of the Marshall branch is 12.8 miles, Louisville branch 12 miles, and the Denver line 15.2 miles.

In this case it is obvious that there will be material advantage gained by being able to operate each branch independently, and provision has been made accordingly; but by-pass feeders for each branch would not help matters much in case of line trouble. The trolley wire, in this case, as with the Erie, has been provided with section breakers placed about 4 miles apart for convenience in locating faults.

There are other things to be taken into account besides the actual line trouble; that is to say, the problem is not merely to locate and repair the fault. On any railroad provided with

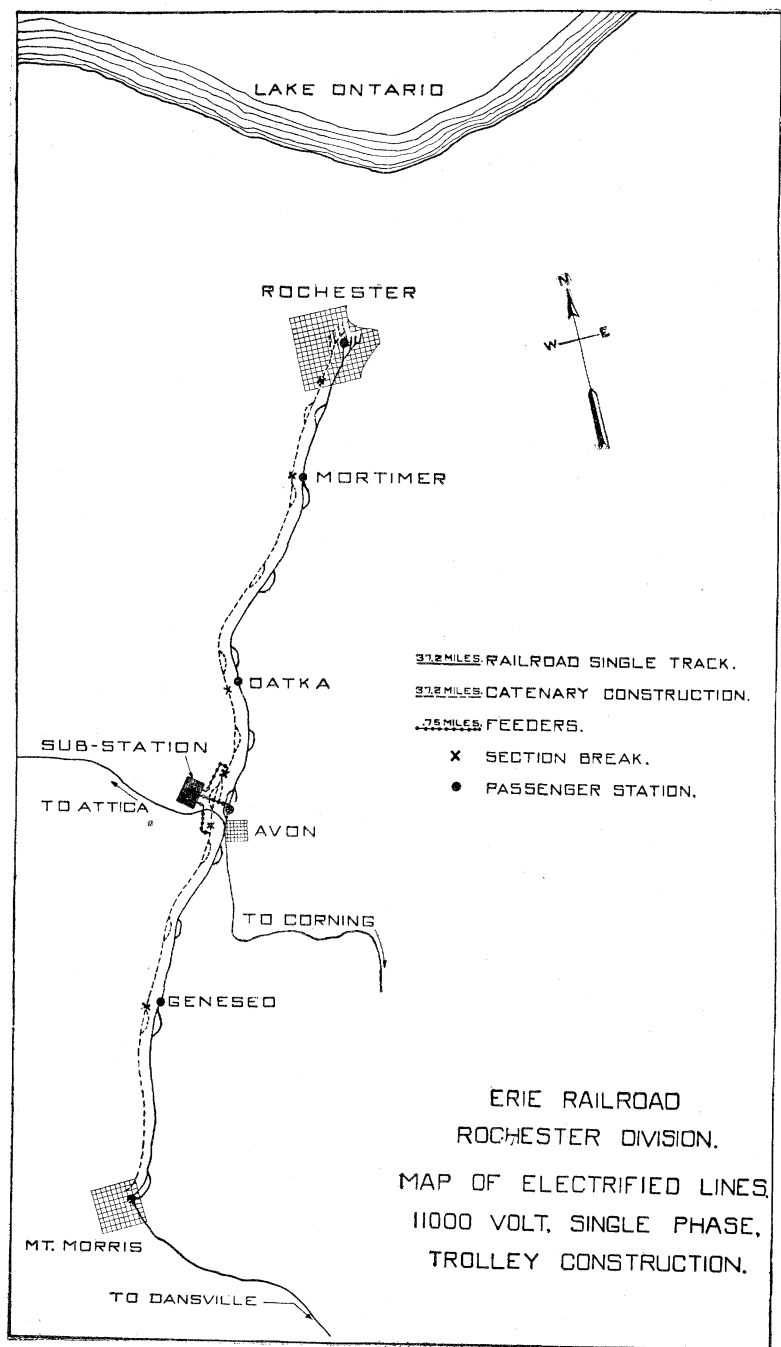


FIG. 1

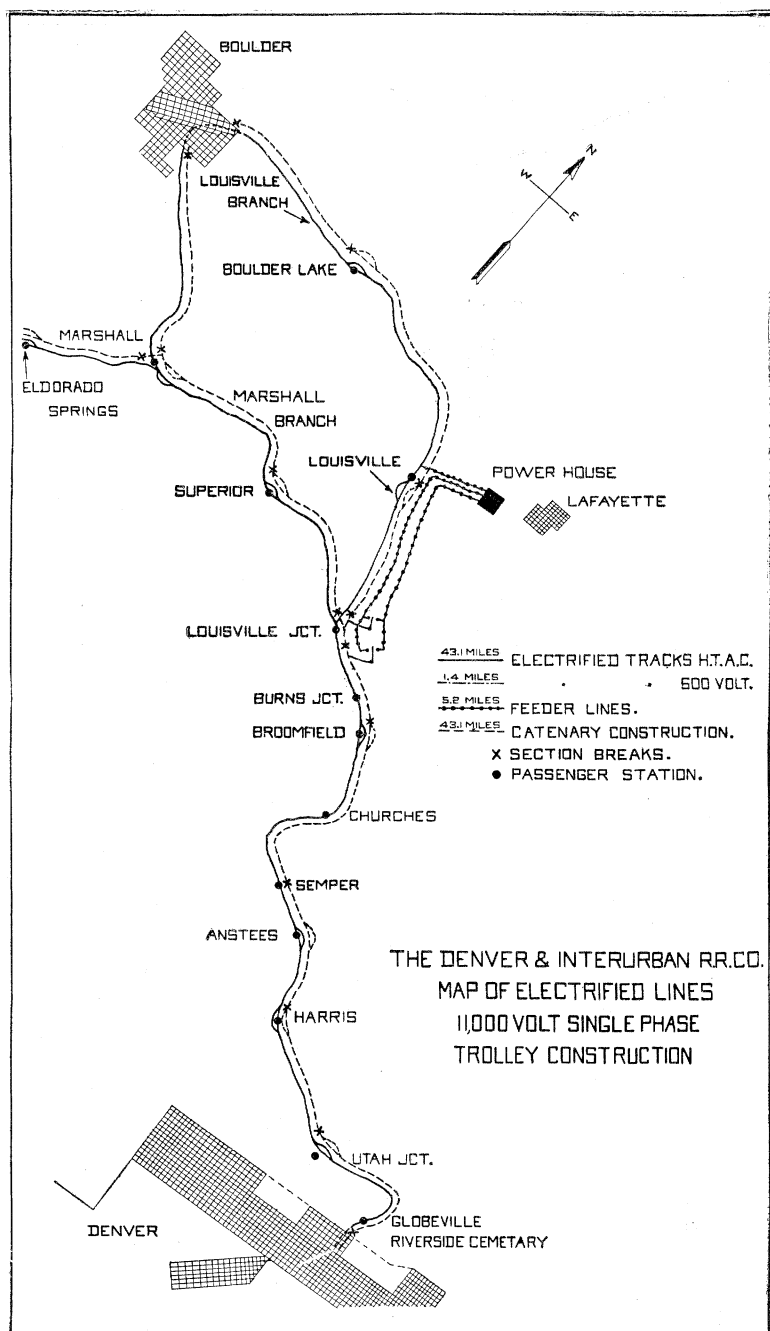


FIG. 2

a positive block system, the process of having the rules set aside so that a "special" can proceed against the block is about as difficult as to repair the fault itself. Most of the time of a service interruption is consumed in reaching the fault, not in locating or repairing it. Sectionalization does not help this part of the problem.

The natural answer to all of this is that the high-voltage trolley system must be put up so that line troubles rarely occur. That looks like quite a task with 11,000-volt operation, but as one gets acquainted with this high voltage construction most of the difficulties disappear. One important feature, according to present practice, is the exclusive use of porcelain for insulation. At first it looked as if the porcelain could not safely be subjected to the heavy physical strains of the catenary construction, but it has been found that standard forms of insulators, when properly harnessed, can be tested out with 14,000 lb. compression and 22,000 volts electrical strain at the same time. Thus far the physical strains in the catenary circuits do not exceed 5,000 lb. per wire, and there will be a factor of safety of about three for an insulator in a single wire or half that, if one insulator is used for both messenger and trolley wires. The use of built-up insulators is not promising. The use of wood, although the wood may be a good insulator, has the objection that if there be leakage across the wood and the wood be burned in two, then down comes the catenary construction. With porcelain properly harnessed, the only result of a broken insulator is reduced insulation. The line does not come down, because the harness is interlocked. With two insulators in tandem, the line will remain operative.

Mr. Murray's third recommendation of 22 ft. for general working distance of the trolley from the rail, seems to be about right, as has been said once or twice this evening, and this means a standard clearance of 24 ft. above the rail for the "through" and "under" bridges, and still greater clearances for other overhead structures, whenever physical conditions permit. In a large majority of cases (barring tunnels and city street-crossings) new construction can be designed for 24 ft. clearance without much difficulty or material effect in cost. The troubles of the electrical engineer will be materially reduced if the railways will make this the standard clearance for new construction.

The feature of high insulation factors for construction under low bridges should be characteristic throughout the entire installation, for the reasons which I have given. There is no reason for not having such an insulation factor.

Mr. Murray also speaks of the auxiliary wires passing under bridges, and advises the use of lead-covered cables with end-bells. A short section of insulated cable, in a grounded sheath, in the middle of a long overhead line, is a mighty difficult thing to install properly so that the insulation will not be frequently broken down. Inasmuch as the trolley wire has to go under

the bridge, and the trolley must be bare, it would seem possible to put the auxiliary wire under the bridge in much the same way, and with equal safety.

One gratifying feature about catenary construction erected on grounded brackets or grounded bridges is that there are grounded structures close to and frequently above the live wires, and consequently little probability of disturbance from lightning. The Rochester division of the Erie road has been in operation for about eight months, and through nearly all the lightning season of last year there was practically no disturbance on the 11,000-volt system due to lightning, although there were bad thunder storms through that district, and a nearby high-tension line was struck repeatedly. On the other hand, in the single-phase system there occur occasionally heavy disturbances resulting in surges approximating lightning in severity, and if anything but porcelain be used for insulation (for instance, in the case of lead-covered cables above referred to) I should anticipate that such surges would occasionally break through the insulation.

On this Rochester division there is a telephone system on the same poles with the trolley line. With proper transpositions and suitable means for removing the "static" from the telephone line, it operates satisfactorily and without shock to the operators.

W. S. Murray: I am happy to feel that Mr. Stillwell bears me out along the ideas of a practical investigation. I think that mental reservations on this floor, where our mistakes may be brought out and discussed, is a great error. Our mistakes teach us more than our theories, and I think this floor is the place to discuss our troubles as well as our successes.

Mr. Potter spoke of pinning his faith to the third-rail instead of the overhead construction. In regard to that, I can simply say this is a problem much larger than the one we are discussing to-night; but I have reason to believe that on long-distance traction work the question of operating expense will unquestionably be the paramount feature, and hold the overhead construction and alternating-current transmission direct to motors a necessity. I can almost say that experience bears me out in this regard, even within restricted zones of electric traction.

I think that the necessity of two feeders can be explained quickly by saying that in the event of trouble the interlocking of the feeder system as established on the New Haven road is such that if trouble occurs on one feeder, by by-passing around through switches on the anchor bridges we are enabled to cut out any feeder-section and make repairs, thereby giving a more reliable continuity of service.

I thoroughly agree with Mr. Potter that the sections should be greater in length. I think that from three to five miles sounds reasonable, but local conditions govern better what the actual distance should be. I am quite convinced that were we to draw

up specifications for the New Haven electrification again, I would be in favor of a longer section. This, as brought out in the paper, does not interfere with the conterminous arrangement of towers, which is most important.

In regard to pantographs operating under low bridges, Mr. Potter has brought out an important and deleterious feature of the overhead system. It is a problem that must be solved. We first started our electrification by a system of supports under low bridges, at very short intervals, and the result was, due to the effect of the locomotive blasts, that grounds developed very rapidly. This trouble has been overcome by eliminating the large number of supports, resorting to only two; and, instead of having the insulation in the middle point directly over the track, as at first installed, it has been placed at the side, so that the locomotive blasts do not affect the main insulators. Since we changed the construction to the latter arrangement, we have experienced absolutely no trouble in the grounding of the contact conductor (or messenger cables which are connected to it) under low bridges. This form of construction has been in use for four or five months.

In regard to the fact that for mechanical reasons we have to increase the copper in overhead construction high-tension work, the fact also must not be overlooked that the total copper is still in a minute ratio to the amount of copper required for an equivalent amount of power with the same loss transmitted on the alternating-current—direct-current system.

Operating the anchor bridge switches by levers would bring an increase of operating cost. I do not approve of this, particularly as lever arrangements in switches have been abandoned as cumbersome in places where quick action is required, and such a place as the operating towers calls for quick action.

In general, I agree with Mr. Lyford about the single-track feeder arrangement. In its application to long distances, however, I think a feeder arrangement for single-track construction is quite necessary, particularly where the headway is short and the traffic heavy. Should such trouble as he spoke of develop in the middle of the line, it is not uncommon in railway practice to operate to that point on both sides. In such a contingency the feeder or by-pass offers quick relief; it is not costly, and is constantly saving power. I certainly agree with him in regard to porcelain insulation in the place of moulded material, if it is possible to obtain the tension and compression strains in porcelain that is obtained in molded material.

Mr. Lyford's suggestion to use the same form of feeder construction under low bridges as is adopted in the trolley is a good one, provided the clearances can be obtained under the low bridges in question. Abutment walls are so near to the tracks that it becomes a rather difficult thing to put in this kind of construction, especially if, besides feeders, other wires, such as power wires and signal wires, have to be taken care of.
