COMMUNICATIONS

Mr. Sprague on Regenerative Braking

NEW YORK, May 19, 1915.

To the Editors:

I note that the ELECTRIC RAILWAY JOURNAL has been giving considerable editorial attention of late to the subject of regeneration of electrical energy in heavy electric traction. As I have been engaged in pioneer work along regeneration lines for many years you may be interested in a few historical notes regarding this work. It has been based upon the principles which first found their development and practical application in my constant-speed electric motors developed for stationary work some thirty years ago in the early days of this art. At that time I pointed out that in order to get constant speed under variable load, with a shunt motor supplied from a constant-potential circuit, it was necessary automatically to vary the field magnet strength inversely with the load, and therefore the motor or counter emfs, so as to vary the effective or differential emfs and currents directly with the load.

The principle underlying this regulation, applied to motors with shunt fields alternately driving a load or being driven by one, of course indicated that when so driven by a load the raising of the motor emf above that of the source of supply would produce a reversal of current and consequent delivery of energy to the line.

The first practical commercial application of this principle that I know of was in my use of shunt-wound motors to drive line shafts from which balanced freight elevators were operated by direct and reverse belts. In such cases when a load was being lowered it drove the motor at a slightly accelerated speed and delivered current to the line, thus making it possible to operate a very large number of elevators from a common source of supply with a minimum total expenditure of current.

I early developed this principle in its application to railway work, and in December, 1885, before the Society of Arts in Boston, outlined at length a method of electrifying and operating the Manhattan Elevated Railroad, so that by using shunt motors and the principle of shunt-field regulation it would be possible to save fully 60 per cent in the size of the central station and in the amount of power required, because every car or train running on a down grade, or approaching a station at a speed above a certain value, would constitute a moving supply station to supplement the main power station in providing current for cars accelerating, ascending a grade, or operating at constant speed.

Such operation was demonstrated for a considerable period on a platform car at the old Durant Sugar Refinery on East Twenty-seventh Street, New York, in 1886, and for some months on the Thirty-fourth Street branch of the Elevated Railroad in the winter of 1886-1887. At this time I used shunt field variation, not only for speed control but also for first delivering current back to the line in slowing down the speed of a car, and then, breaking away from the line, for bringing the car to rest by sending the current generated in the armature through a diminishing resistance until finally it became practically a short circuit, the field still being connected to the line. In the public tests in this connection the car was often handled entirely without the ordinary wheel brakes.

The method of operating trains with shunt-wound, constant-potential motors had two difficulties, one being a lack of starting torque as compared with a series-wound motor, and the other that success in using this method of regeneration required motors of similar characteristics and wheels of like diameters, or methods of adjustment to take care of any differences which might exist. With these factors equalized there was no question of the remarkable efficiency of control and saving of energy.

In 1886 I extended my patents to cover the application of the same principle to the recharging of storage batteries when used upon a street car. I think that I am correct in stating that these various patents and the principles outlined in them marked the first recognition of the possibility of the use of a regenerative principle in a practical way.

Since that time a great many uses have been made of this scheme. One very common one was that developed by me about 1890 in connection with elevators operated against gravity. In my earlier multiple-sheave screw machines the load was always against the machine, that is, even with no load in the car the weight was unbalanced by, say, 600 lb. or 700 lb., enough to rapidly overhaul the machine. The motors, therefore, on the up-trip always worked against a load, but on the down trip the armature was detached from the source of supply, closed upon an adjustable rheostat, and the speed of the car was governed by the retardation so established. The safety device at the bottom operating on failure of current also made use of this principle.

On the Central London elevators, which represented by far the largest elevator equipment ever put in at the time of its installation in 1897-1898, the operation was on similar principles, except that in this case the elevators were practically counter-balanced, so that the motors were sometimes driving and were sometimes driven in each direction of movement. This resulted in material economy.

Various attempts have been made in recent years to apply this principle to series-wound motors in operating street cars, and a number of tests were made in England in this connection. In the application of polyphase motors to railway service the principle of regeneration to line was, of course, the natural application of their shunt-wound motor characteristics. Following this application in Italy various plans have been advanced for using the regenerative principle in connection with single-phase motors, although the problem in this case is not by any means so simple, especially if it be desired to use all the motors of an equipment. Incidentally, I had, on the first modern electric railway installed in Italy by my assistant in 1890, used this same principle as a special safeguard made necessary by a grave accident occurring shortly after the opening of the road. After this accident it seemed important to put into the hands of the conductor the ability to take the control of the car acceleration out of the motorman's hands, and to make the car act as its own braking power.

Later, I proposed for d.c. motors on mountain duty the use of the regenerative principle, primarily for braking or checking the train on a down grade, using all the motors, not for sending current back to the line but for generating current under controlled resistances upon the locomotive, the motors being self excited with reversed armature connections. This was not done for purposes of power economy but primarily to avoid the disastrous consequences of over-heated brakeshoes and wheel rims after long brake applications, and the failure of air supply when perhaps unduly overtaxed. In this case the braking could be alternated or divided between motors and air brakes.

I proposed this plan practically for a suggested electrification of the Sacramento division of the Southern Pacific Railroad over the Sierra Nevada mountains in

1907, 1908 and 1909. A variation of this use of motors as self-exciting generators on a locally closed circuit is to use a line-excited motor-generator to excite the series field coils of the motors, leaving the armatures connected with the line so as to be able to receive current from, or send back current to it, with provision for changing the connections so as to get local self-excitation for rheostatic braking in case of necessity.

This later plan, like many others which I have found necessary to carry through in the face of doubt and criticism, did not meet early acceptance, but it is probably the method which must be adopted at least with direct current motors. FRANK J. SPRAGUE.

Investment Per Passenger

SLOAN, HUDDLE, FEUSTEL & FREEMAN
CONSULTING ENGINEERS

MADISON, WIS., June 2, 1915.

To the Editors:

I have noticed the article by D. J. McGrath in the ELECTRIC RAILWAY JOURNAL of May 8, and was much interested in finding that a study was being made to show more clearly to the public just what application was made of the fare received by street railway companies from its patrons. The studies described by Mr. McGrath represent, to my mind, the first step in presenting this matter properly to the public.

In my work with a considerable number of public service commissions throughout the country who are regulating rates for utility commodities, it has usually developed that when the consumer came to a clear understanding of the basis for the charge which was being made upon him, he was willing to pay fairly for the cost of the service which was being furnished.

Unfortunately, due to the operation of certain misguided public utility men, who were really financiers and not operators, the problem of convincing the public that utilities of various kinds are not a veritable gold mine has been a difficult one. The wide variation in the laws governing the issuance of utility securities has helped to increase the doubt in the public mind. Published extracts from annual reports of utility companies indicating satisfactory dividends, some times issued for financial purposes, have also added fuel to the fire of mistrust. As pointed out in Mr. McGrath's paper, the past practice of indicating the investment per mile of track or per dollar of gross revenue has been unsatisfactory not only to the public but to the trained operator. The varied conditions which obtain in small and large city construction, where street improvements and varying length of haul play such an important part, make these figures of little value. We must, therefore, find some method of presenting these facts in terms simple enough to be readily understood by the average patron.

I believe that further development should be made along the lines suggested in the article and units should be prepared which will further divide the average fare so that the patron can see at a glance its various applications. For example, in the case of the Manchester Street Railway Company, of Manchester, N. H., which was cited by Mr. McGrath, the investment per passenger would be somewhat misleading, as he points out, due to the fact that this company is purchasing power and does not have any investment in a power station. We would, accordingly, expect to find its operating expenses for power charges greater than that of a company furnishing its own power.

I believe, therefore, that it is necessary to take additional steps to show the application of the total amount of the average fare received per passenger to all the fixed and variable expenses which enter into the cost of furnishing street railway service. If this were done, in many cases patrons of the city lines would be very much surprised to find out the portion of the average 5-cent fare which goes toward paying a fair return on the investment, and that which goes for operating expenses and depreciation.

ROBERT M. FEUSTEL.

Traffic Characteristics

AMERICAN ELECTRIC RAILWAY ASSOCIATION
BUREAU OF FARE RESEARCH

NEW YORK, June 2, 1915.

To the Editors:

In the article on "Traffic Characteristics," appearing in the issue of the ELECTRIC RAILWAY JOURNAL of May 15, the descriptive titles of Fig. 3 and 4 (pages 927 and 928), have been transposed. Probably no confusion resulted from this, as the units of each scale are shown in the figures, but I am taking the liberty of calling the matter to your attention in this manner, in order to remove any possibility of confusion.

The method of construction of these models may be of interest.

On a sheet of cross section paper there was first laid off a horizontal line representing to scale the distance between points where traffic observations were made on a typical line.

Ordinates were next erected at each point of observation, representing to scale "total passengers" or "passengers per car" observed at that point. The plotted ordinates represent "hourly rates"; that is to say, where the total number of passengers passing a point of observation was, say 200 from 3:30 to 4:00 p. m. and 300 from 4:00 to 4:30 p. m. The ordinate erected at that point of observation would be drawn to represent 500 passengers per hour.

The next step was to connect the ends of the ordinates by a curve. The cross section paper was then pasted to a sheet of cardboard and cut along the base line and the curve connecting the tops of the ordinates. This process was repeated for each of the twenty-four hour-periods of a typical day. Values used in this work were averages determined from observations extending over a period of three days.

The twenty-four cardboard curves were next arranged in order, in notches sawed in the board which forms the basis of the model. The position of these cardboard strips is shown by the dark lines transversing the figures. Between the strips a plastic material was placed, and each of the twenty-four prisms was smoothed off to conform with the trend indicated by the adjoining prisms. The resulting surface was finally painted and varnished.

F. W. DOOLITTLE, Director.

The Nashville Railway & Light Company, Nashville, Tenn., profiting by the experience of the Knoxville Railway & Light Company, Knoxville, Tenn., is enlisting the interest of the pupils in the public schools in the safety-first work it is doing. Blotters on which there are pictures of typical accidents that are the penalties of carelessness and "hooking rides" have been distributed among the children of the schools and the teachers are having the pupils write short articles on the impressions gained from the pictures. The Knoxville Railway & Light Company provided a schedule of prizes, in the form of free-ride books, each containing tickets for fifty rides. The local company may follow the same course next season, but as the school term will soon be over no action of the kind will be taken this summer.