AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

SPECIAL MEETING, OCTOBER 21st, 1890.

The meeting was called to order by President Anthony at 8.20 P.M.

The Secretary read the names of the newly elected associate members.

THE SECRETARY:—The next business is the report of the Committee to determine the value of the “henry”; and the revision of the preliminary report of the wiring table committee is also to be acted upon.

MR. FRANCIS B. CROCKER:—I can report for both committees. As I said at the last meeting, the reference of these matters to committees would probably involve a delay of several months. I have tried to have several meetings, without very much success. but we have about half done the work, I should say, and probably by next meeting we will be able to report the result in finished form. The question of the value of the “henry” is rather an important one, and if we are going to recommend a value different from that of the quadrant we want to be perfectly sure that we are right and that it will fit the requirements of practice. So I report progress for both committees.

THE PRESIDENT: (Prof. W. A. Anthony)—The first paper for the evening will be on “Investigation of the Stanley Alternate Current Arc Dynamo,” by W. B. Tobey and G. H. Walbridge.

*A paper read at the 50th Meeting of the American
Institute of Electrical Engineers, New York,
October 21st, 1890, President W. A. Anthony in
the chair.*

INVESTIGATION OF THE STANLEY ALTERNATE CURRENT ARC DYNAMO.

BY W. B. TOBEY AND G. H. WALBRIDGE.

BEFORE entering directly upon the subject to be presented this evening, *i. e.*, the investigation of the Stanley alternate current arc dynamo, it may be well to give a brief description of that new and extremely novel type of machine. Descriptions of it have been given in some of the electrical papers during the past spring, but some here may not recall its general mechanical construction. The dynamo is manufactured and sold by the Westinghouse Electric Company under patents granted to Mr. Wm. Stanley, Jr., the inventor. Mr. Albert Schmid, superintendent of the Westinghouse Electric Company's shops, deserves much credit for perfecting the machine in detail, and to him is largely due its success commercially. In general appearance it closely resembles the Westinghouse alternate current constant potential dynamo, which has become so familiar to all. In fact, the frame, pole pieces, field windings, etc., for any given size machine are identical, whether for constant current or constant potential. The distinguishing feature between them lies wholly in the form and winding of the armatures. Figs. 12 and 13, showing diagrammatically half sections of the machine, will aid us in a description of the armature, which is built up of thin iron plates stamped in the form shown. It will be observed that a number of cores corresponding to the number of poles of the dynamo project radially from the armature, and from the sides of each core project overlapping lugs. The armature coils are not of the original "pancake," or oblong flat coil type, placed on the periphery of the armature, but are quite thick and placed around the core projections. The overlapping lugs serve the double pur-

pose of preventing the coils from slipping off the cores and also aid in the regulation of the machine. All the armature coils are connected in series and the terminals connected to the two collector rings, upon which bear the brushes furnishing current to the line. The field coils are also in series, so connected that the poles presented to the armature are of alternate polarity. The terminals of the field go directly to a small shunt wound exciter. Thus it is seen that the machine consists simply of an even number of field coils, corresponding to the number of poles on the machine, joined in series, and an equal number of armature coils also joined in series. That from such a simple combination of coils without any external regulating device, an almost constant current is obtained for all loads, from short circuit to

Fig. 1.—DIAGRAM OF CONNECTIONS.

A, A, A. Ammeters; V. Voltmeter.

the maximum output of the machine, seems incredible, but such is the case.

Through the kindness of Mr. Stanley, a complete 40-light plant was sent the writers at Cornell University, at which institution we were then students. Later, the Westinghouse Company made the University a gift of the entire plant. It has been our aim to show how the regulation takes place; also to determine the actual electrical output of the machine, and from the later and the corresponding dynamometer readings, to calculate the efficiency of the dynamo.

The alternator was mounted on a Brackett cradle dynamometer calibrated to read in watts direct at 1000 revolutions, the speed at which we were running.

The general method has been to obtain instantaneous values of E. M. F., arc and exciter currents at a sufficient number of points to indicate by curves the performance of the dynamo at every part of a revolution. For this purpose runs were taken with the dynamo at short circuit and with loads of 5, 10, etc., up to 40 lamps. The dynamo was run under normal conditions, viz, at a speed of 1000 revolutions and with such excitation as to cause an output of approximately 10 amperes. For obtaining values of E. M. F. at low loads, pressure wires were run from the terminals of the dynamo and for larger loads were taken from around 10 lamps. At all points where instantaneous values of E. M. F. were taken, corresponding values of arc and field, or exciter currents

Fig. 2.

were obtained by "fall of potential" method. Pressure wires were brought from the terminals of each of two non-inductive resistances of german silver wire placed in arc and field circuits. (See Fig. 1.) These resistances being constant, any pressure around the terminals corresponded to a certain current. The terminals of the three pairs of pressure wires were connected to the contacts of the triple-throw switch, so that by placing the switch on any pair of contacts desired, those terminals could be put in circuit with a line in which was a condenser and the revolving contact or commutating device by means of which the condenser was charged. The revolving contact used was similar to the one described in detail by Prof. Ryan in his paper on "Transformers," read before the Institute last December.¹ It

1. SEE TRANSACTIONS OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, Vol. vii., p. 1.

consists essentially of a knife-edge of steel fastened by a wooden clamp to the collector end of the armature, and revolving with it through a circle of about eight inches diameter. The centre of the knife-edge was in line with the centre of one of the armature coils. Upon a frame at the same end of the armature was held a wooden semi-circle, upon the periphery of which was a paper scale, divided to millimeters. At the centre of the semi-circle was pivoted an arm carrying a brushholder in which was a steel spring. The brushholder was so adjusted that the revolving knife edge made contact with the spring several times per second. The arm carrying this spring could be clamped wherever desired,

Fig. 3.

and its position designated by means of a pointer over the scale.² Thus, the condenser, placed in series, could be brought to the same difference of potential that existed between the spring and the knife-edge. The arc circuit was, as shown by the diagram of connections, Fig. 1, taken from one brush directly to a Westinghouse ammeter through a switch, by means of which a Thomson balance, or gravity ammeter could be put in circuit when desired. From the Westinghouse ammeter the current was taken through the non-inductive resistance to the dynamo short circuiting switch, where the other terminal of the machine was directly connected. The exciter current was measured by a Ryan gravity ammeter, and a Hartmann and Braun type voltmeter

2. Much trouble experienced by other investigators in this line, due to breaking of the spring, was entirely obviated by us by putting a piece of thin rubber packing above the spring where it was clamped in the brushholder.

indicated the potential around the terminals of the field. The arm of the commutating device being clamped at some desired position, the spring was adjusted so that the revolving knife-edge made contact, then the switch was thrown on any one of the three pairs of terminals, for the circuits of which we wished to obtain instantaneous values. The half microfarad condenser was so connected that by closing a key it would be charged. Opening this key and closing one in circuit with the galvanometer, sent the charge through the galvanometer and the throw was noted.

The galvanometer used was 5000 ohms resistance, and consisted of the coil of a Sir Wm. Thomson marine galvanometer, in which was suspended a small, concave mirror, having several

Fig. 4.

very small magnets constituting the needle, fastened on the back. The controller was a large horse-shoe magnet. A simple wooden frame supported the coil. A narrow slit in a screen, behind which stood an incandescent lamp, allowed an image of part of the filament to fall on the galvanometer mirror and be reflected back to the screen, on which was a graduated scale. By placing a resistance box in shunt around the galvanometer, the throw of the needle was reduced when it was desired to read the arc E. M. F. When current readings were taken, the whole charge of the condenser was passed through the galvanometer. The galvanometer was calibrated for E. M. F. by putting the condenser and a standard potential instrument in multiple around the terminals of a storage battery giving about 120 volts. Readings were then taken

of the voltage, and the corresponding throw of the needle was noted. The calibrations of currents were made by running the exciter alone and passing the current through both of the non-inductive resistances, determining its amount by an ammeter, and observing the corresponding throw of the galvanometer needle for each non inductive resistance.

So much for a description of the dynamo, the instruments and the methods used. We now come to that which is of most interest, viz., the results obtained. In order that the curves may be more easily followed we will give a brief general explanation of them.

The figures on the zero line, always commencing with 5, cor-

Fig. 5.

respond to the divisions on the scale of the wooden semi-circle, a part of the commutating device. Under each plate of curves will be seen two rectangular figures, representing pole pieces, which show the relative position of the curves with respect to the poles. From each curve projects a vertical arrow, always equal to one or two divisions, and its value marked near it. In all curves the direction or motion of the armature relatively to the poles is from left to right.

Fig. 2 represents the performance of the machine at short circuit. The curves of E. M. F. and current both approach sine curves; the current rising almost in unison with the E. M. F., there being no perceptible lag. The curve of exciter current in

this, as in all cases, exhibits a wavy form. Fig. 12 shows the position of the armature relatively to the poles when the E. M. F. is zero and the machine running on short circuit.

Fig. 4, representing the curves for a load of five arc lamps, shows a radical change in the E. M. F., which now approaches more nearly to the form of a rectangle than a sine curve, and immediately after passing the zeros exhibits very sharp peaks. In this case the current continues to rise after the E. M. F. has begun to fall, and also lags slightly with respect to it. A shifting of the zeros has also taken place. Comparing this E. M. F. curve with that for short circuit it is seen that the first zero shown occurs at about 6.35 instead of 6.85. The curves for all loads of

Fig. 6.

arc lamps are quite similar in form. as will be seen by referring to Figs. 5, 6, 7 and 8. As the load is increased, however, the zeros occur earlier with respect to the poles, and the current lag increases slightly. The efficiency curve, Fig. 9, tells the story of the dynamo from a commercial point of view, reaching as it does an efficiency of between 93 per cent. and 94 per cent. at full load while at half load it is 92 per cent.

A most interesting set of curves is shown in Fig. 10, giving a comparison of the forms and values of E. M. F. for 40, 30, 20, and 10 lamps, their position with respect to the poles, and also the position of the zeros of E. M. F. at short circuit.

Figs. 13 and 12 show respectively the positions of the armature relatively to the poles for full load and short circuit.

An apparently remarkable feature of the machine is that it may be short circuited when running at full load, without the slightest injury, and it may be run at short circuit indefinitely.

Fig. 7.

That the machine regulates with great rapidity is proven by the fact that upon short circuiting it, the ammeter indicates but a slight increase of current. The peculiar form of the E. M. F. curve for arc lamps led us, so far as time would permit, to an investigation of the cause, to ascertain which the following runs were taken :

Fig. 8.

First, with a non-inductive resistance of five large incandescent lamps, but no arcs in circuit; each lamp consuming about the same amount of energy as an arc lamp. Second, with noth

ing but an inductive resistance, consisting of a solenoid having 440 turns of No. 10 wire. The curves in both cases were similar and approached sine curves, proving the rectangular form to be

Fig. 9.—EFFICIENCY CURVE.

due entirely to the action of the arc. Fig. 3 shows the curves obtained from the load of incandescent lamps. To more fully determine this action with no other resistance in circuit, an arrangement was made whereby an arc could be regulated by hand with the aid of a hot wire voltmeter. We took no curve for a single lamp under normal conditions with which to compare the one taken in the above manner; but the latter (see Fig. 11) has very high and abrupt elevations of E. M. F. immediately before and after passing the zeros. The theory advanced to explain

Fig. 10.

the high point of E. M. F. in all the arc curves is, that when the arc breaks, the rush of cold air adding resistance to the circuit, prevents the arc forming again until the potential has risen to a

point considerably higher than that required to maintain an arc once formed. To test this we attempted to heat an arc by means of an alcohol blast, and thus prevent, in a measure, the rush of cold air. This means of heating proved inadequate, so that the results were not all that could be desired. As before stated, we had no one-lamp curve with which to compare it, but as compared with the one lamp regulated by hand, the sharp corners of E. M. F. were much modified. It is not certain, however, whether this was due to the action of the lamp regulating coils, or to the action of the flame. The current curve in all cases approaches a sine curve in form, but is always slightly steeper on the left or front side; direction of rotation being from left to right. Although the current lag is practically nothing at short cir-

Fig. 11.

cuit, or for any load except arc lamps, it increases slowly as arc lamps are added. For 40 lamps it is about $4\frac{1}{2}$ per cent. of the time of an alternation. The wavy form of the exciter current is probably caused by the variable resistance of the magnetic circuit, due to the projecting cores and lugs of the armature as they approach and recede from the poles. The values of E. M. F. and current were found by taking the square root of the mean square of 36 ordinates of a curve, representing a complete circle. Although the current lag was very small, the product of the values of current and E. M. F. obtained as above did not give the watts. The watts were obtained by plotting a curve, the points of which were the products of the instantaneous values of E. M. F. and current; then integrating by a planimeter. Dividing the value

of the watts thus obtained by the current, we obtained a value of the E. M. F. which was usually about seven volts lower per lamp than the corresponding value obtained from the square root of

the mean square. This difference was no doubt due to the extremely high values of the E. M. F. when the current was very low, as the negative work was negligible. To distinguish between the two values we have called the one obtained from the square root of the mean square, the "actual" E. M. F. while the one obtained by the second method has been called the "effective" E. M. F., it alone being effective in doing work on the circuit.

It is very much of a question in our minds as to whether the square root of the mean square, obtained from the rectangular E. M. F. curves for arc lamps, gives the actual E. M. F., but for the

lack of a better term, the values thus obtained have been called the actual E. M. F's.

For arc current values we have assumed the square root of the

mean square to be correct, and if not actually the case, they are certainly very close approximations, as the current curves are practically sine curves. The exact values of E. M. F. or current are of little consequence, however, except as a matter of interest, since the electrical output in watts is known, this alone being required to determine the efficiency.

In conclusion we can simply state that our investigations have shown, that the dynamo, aside from being very efficient and of most excellent regulation, is, as stated at the beginning, an extremely novel and interesting type of machine.

TABLE OF DATA.

	√ Mean sq. of E. M. F.	Volts per lamp "actual."	√ Mean sq. of Current.	Volts per lamp "effective."	Mean watts electrical.	Watts excitation.	Mean watts by dynamometer.	Efficiency.
Short Circuit.	3.53		9.78		35	155	1780	
5 Incandescent.	289.	57.8	10.32	59.3	3060	158	3900	75.3%
5 Arc.	285.	57.	9.98	50.	2500	165	3584	66.6%
10 Arc.			10.7	53.3	5700	190	6630	83.5%
20 Arc.	1100	55.	10.36	48.3	10000	190	10680	92.3%
30 Arc.						204	12120	
40 Arc.			9.82	41.	16000	240	16950	93.2%
1 pr. carbons.	42	42.	8.86	35.5	314			

THE PRESIDENT:—As the paper of Mr. Reid applies in the same direction, that will be read before discussion is called for. The next paper will then be "A New Method of Analyzing Armature Reactions, applied to the Stanley Arc Light Alternating Current Machine."