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A DYNAMO INDICATOR, OR INSTANTANEOUS CURVE-WRITING VOLTMETER.

BY GEORGE S. MOLER.

In connection with the work in dynamo and motor testing in the physical laboratory of Cornell University, it was found desirable that some method should be devised which would enable the student experimenting, to very quickly explore the field of a machine, so that he could study some of the changes which might take place even in a few seconds. The double brush method of Dr. S. P. Thompson, and the single brush method of Mr. W. M. Mordey, are in use and give excellent results, but either of these methods requires a few minutes at the very shortest to obtain the data for a single curve.

To attempt to meet this want the writer devised the instrument which is the subject of this paper. It is intended to be used in tracing those curves which show the changes in potential of the two ends of a single coil of the armature, and also those showing the changes between one brush and one of the commutator bars, as the armature revolves. The instrument consists in the main of a very rapidly vibrating needle of a voltmeter, and a smoked cylinder against which the pointer is made to press at the required moment. The curve is traced during a single revolution of the armature, and is then easily transferred to paper, and is thus placed in a permanent form to be studied at leisure. The voltmeter, which is inclosed in the body of the instrument, is of the permanent magnet form. The needle is of soft iron, and is very short, and held at zero by being placed between the poles of a powerful steel magnet. The pointer is made of aluminium and is quite short. It is shaped so as to be as light as possible, and so that the air cannot offer much resistance to its motion. The cylinder is of metal and very smoothly finished, so that it will offer little resistance to the movement of the pointer. It is mounted upon a short shaft and is arranged so that it can be slid to several different positions; a spring dropping into notches holds it at each place. The stationary pivot at *A*, Fig. 1, is made with a spring so that the cylinder can be quickly removed for smoking or for transferring the curves. This short shaft is connected with the driving shaft of the instrument by projecting pins at *B*, so that it will always maintain the same relative position with the pin at *C*. The pin *C* is attached to a sliding sleeve which is pushed toward the point of the shaft by a spring. A hole or a pin in the end of the armature shaft is to engage with the pin *C*, so that

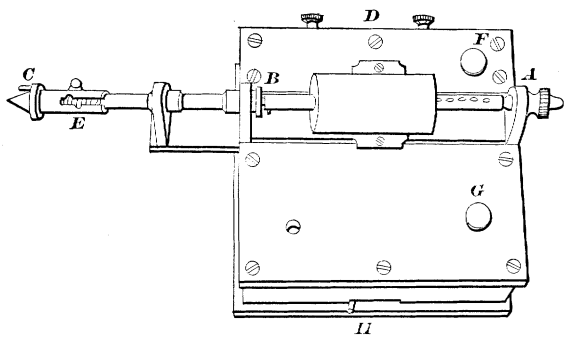

Fig. 1.

the cylinder will always have the same relative position with the armature. To operate the instrument, two insulated wire hoops or bands are to be wound around some convenient part of the shaft or commutator, and one is to be connected to one commutator bar and the other to one of the adjacent ones. Small brushes are to be made to press upon these bands, and they are to be connected to the binding screws at *D*. The cylinder is then lightly smoked by removing it and revolving it over a candle or gas flame; then it is placed in position. The sleeve carrying the pin *C* is pulled back and latched in the notch *E*. Then the point is pressed into the centre hole in the end of the armature shaft; this will put the drum in motion; then by letting the projecting knob strike the finger the sleeve will be unlatched, and will spring forward and engage with the pin in the end of the armature shaft. Then pressing the button *F* closes the circuit, and pressing *G* brings the pointer against the drum. *H* is a reversing switch. The base line of the curve is drawn by pressing *G* only. Another form of curve will be obtained if one of the terminals of the indicator is attached to one of the permanent brushes of the dynamo, and the other to one of the brushes pressing upon the band connecting with one of the commutator strips. Also a temporary exploring coil may be wound upon the armature, and its terminals may be connected to the indicator.

The voltmeter of the indicator is necessarily one of low potential, so that the changes in a single coil will produce a suitable deflection. For greater changes of potential a resistance must be used in series with it. The curves are transferred from the smoked cylinder by dampening a sheet or paper and then rolling the cylinder over it. Three distinct copies have in this way been made from one set of curves. One of these instruments has been built and has been tested in various ways and is found to give very satisfactory results. The rate of vibration of the needle was determined while the pointer was in contact with the revolving drum and was obtained as follows :—A current was applied so as to produce a deflection, then while the drum was revolving brought in contact with it and the circuit was then broken, making a wavy line extending part way around the drum before it died out. The average rate of oscillation as determined from over 40 measurements was 103 per second, and the damping effect was so great that in .04 of a second the needle was brought

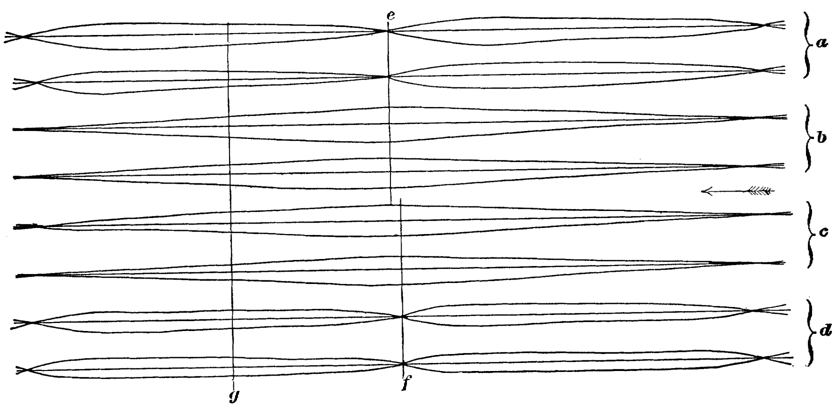

Fig. 2.

to rest. It was also observed that the deflection was not changed by bringing the pointer in contact with the revolving drum.

One of the desirable features of the indicator is the rapidity with which the curves can be made. The cylinder-full of curves, eighteen in all, with their base lines, was made in 73 seconds, so it is seen we can explore the field many times while a dynamo is charging up just after being started, or while any great change in load is being made.

In Fig. 2 are shown some of the curves produced by exploring the field of a 20-ampere shunt-wound dynamo of the consequent pole type. The dynamo was driven at a speed of 1075 revolutions per minute, and had an automatic regulator, which held it at 115 volts, with slight variations. The curves *a* and *b* were made while 20 amperes were flowing in the main line, and *c* and *d* while the outside circuit was broken. The curves *a* and *d* show the changes in potential of the two ends of a single coil. The line *g* shows the position of the centre of the pole piece, and the

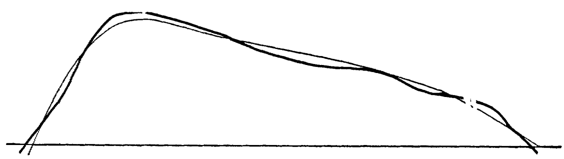

Fig. 3

arrow the forward direction of the curves. The double curves upon each base line, were made by reversing the terminals by means of the switch *H*. The line *e* is the position of the neutral point when 20 amperes were flowing, and *f* its position when the line is open. The difference in shape of the curves shown at *a* and those at *d* is very marked. The curves *b* and *c* were made by connecting one terminal to one of the dynamo brushes, and the other to one of the brushes connected to one end of a coil. These also show the change of the neutral point, and a change in shape for open and closed circuit.

The instrument is calibrated by comparison with a standard voltmeter. For each reading on the voltmeter a line is drawn around the drum. When the pointer is not in contact with the drum some of the effects of inertia can be noticed, but when contact is made they seem to almost disappear, and corrections may be applied to compensate for the lag on that account.

To test the reliability of the instrument one of the 20-ampere curves for half a revolution and similar to *a* Fig. 2, was taken at random, and compared with data obtained by two students. The heavy line, Fig. 3, gives the result which they obtained, working for at least an hour by the usual method. The fluctuations indicate the extent to which irregularities of speed and voltage interfered with the result. The light line shows the same curve as obtained by means of the "indicator."

Physical Laboratory of Cornell University,
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DISCUSSION.

PROF CROCKER:—Mr. Chairman, one point that strikes me in connection with this matter is the fact that the ordinates are so small that the character of the curve is not clearly shown. In other words, the curve is too nearly a straight line to clearly show any particular character. For example, referring to diagrams, Figure 2, they look too much alike. But I suppose a more critical examination, and a little more careful measurement would disclose the true character of the curve, and of course the true character of the action of the dynamo. If this simple apparatus, with all its convenience and rapidity of action, can give a curve which truly represents the curve of the dynamo in a way that is available, it certainly is a very useful instrument. It of course pretends to be an apparatus similar to the ordinary steam engine indicator, and would therefore be very useful to the electrical engineer, and would take the same place in electrical engineering that the steam engine indicator does in steam engineering. There is no doubt that such an instrument is needed—in fact almost required—in electrical engineering, and we would all like to see it perfected. I would like to ask Dr. Nichols if greater amplitude of vibration or height of ordinate could be obtained without introducing errors due to inertia.

DR. NICHOLS:—Prof. Crocker's point is very well taken, and illustrates what may be considered the chief fault of the instrument in its present form. It should be said, however, that while these curves are of such small ordinates that they cannot be readily studied directly, they will bear magnifying. The line is a very fine one, and by measuring the ordinates and multiplying them by some convenient factor, a curve can be obtained which can be subjected to close inspection. This is an inconvenience, but I do not think that it vitiates the instrument where the measurements are of enough importance to admit of this method being used. You expend the time after your test has been made in working it up properly, and you get your measurement in a time so short as to be sure that the results are accurate. I have thought a good deal about the question of increasing the amplitude. I do not know whether it would be practical to multiply it many times or not. I think that without great change in the construction of the instrument the maximum is about reached. Still very likely a further development along these lines might lead to an instrument which would be rapid enough for the purpose, and which would give an ordinate that could be readily studied by the eye.

PROF. ROBERTS:—It seems to me, Mr. Chairman, that the curves might be enlarged, and at the same time the ordinates increased more than the abscissæ by photographing the curves at an angle.

DR. EMERY:—Mr. Chairman, I would suggest also that the diagram can be photographed through a cylindrical lens, as in that way the ordinates can be lengthened without changing the abscissæ. I will say that a similar experience has been gone through with in connection with the steam engine indicator. It is no trouble to enlarge a diagram if the small original is perfect in itself. Generally it will answer to have the measurements made through powerful magnifying glasses, or by a short-sighted person without glasses, and the method of photographing through a cylindrical lens need only be resorted to when it is desired to enlarge the diagram in one direction for the purpose of publication.

The meeting adjourned until 8 o'clock P. M., at the rooms of the Chicago Electric Club.