SOME NOTES ON THE FRANKFORT INTERNATIONAL ELECTRICAL EXHIBITION.[1]

IV.

Alternate Current Motors.

ALTERNATE current motors constitute one of the most striking features at the Frankfort Exhibition, and the commercial use of such motors will probably date from this year, so that the one great objection to the employment of alternating currents for the electric transmission and distribution of power will soon disappear.

It is well known that the direction of rotation of an ordinary series, or shunt, direct current motor is the same whichever way the direct current passes round the motor, in spite of a patent of Mr. Edison's to utilize the contrary fact on electric railways; hence it follows that if an alternate current be sent round such a motor it will start rotating and develop mechanical power. Only a comparatively small power and efficiency, however, will be obtained: first, because the large self-induction of the field magnet of the motor will seriously diminish the strength of the alternating current; secondly, because, in consequence of the rapid reversals of the magnetism, much power will be wasted in heating the iron core of the field magnet, even although this core be laminated like that of the armature.

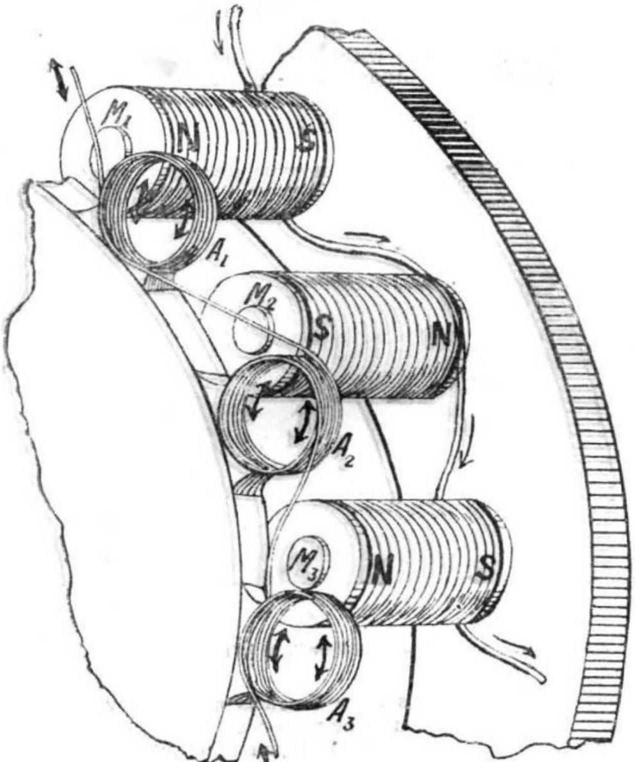

FIG 10.—Alternate current synchronizing motor. ← Direct current. ⟷ Alternating current.

If, on the other hand, a direct current be sent round the field magnet, M_1, M_2, M_3, of an *alternate* current machine, and an alternating current round the armature, A_1, A_2, A_3 (Fig. 10), the armature will not move, because at every two of the successive rapid reversals of the current the armature receives an impulse in opposite directions. To enable such a machine to work as a motor, it is necessary to first make the armature rapidly rotate by mechanical means at such a speed that any armature coil, A_2, moves forward by the distance between two of the poles M_2, M of the field magnet in half the periodic time of the alternation of the current. When this speed has been once attained, the machine will go on running as a powerful and efficient alternate current motor, at a perfectly definite speed, depending simply on the rate of alternation of the current, and independent within wide limits of the load put on the motor.

So that when the armature of the motor is once "in step" with that of the dynamo the two will continue "in step," whatever be the amount, within wide limits, of the power transmitted.

When a considerable amount of power has to be sent from a source to a distant town, and has there to be distributed for light or for driving machinery, it will certainly be best (as far as our present knowledge goes) to use alternating currents in the transmission of the power between the two distant places, because with alternating currents the pressure can so easily be transformed up at the source, and transformed down again at the other end of the line.

But in the distribution of the received power direct currents are the more convenient, since they can be utilized for light, for electroplating and electrotyping,

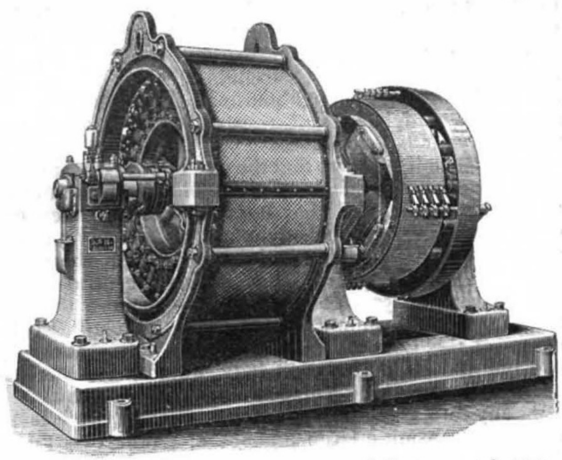

FIG. 11.—Coupled alternate current motor and direct current dynamo.

as well as for small and large direct current electromotors, both of which have already reached a considerable degree of perfection, and are of course self-starting. Hence it is probable that there will be employed a synchronizing alternate current motor, coupled mechanically to a direct current dynamo, the latter being used to supply current to the town and excite the field magnets of the motor. Such combinations, seen in Fig. 11, are exhibited by Messrs. Siemens and Halske in the Frankfort Exhibition, the alternate current motor being to the left and the direct current dynamo to the right in the figure.

In the particular form of direct current dynamo shown in Fig. 11, and which represents a type much used now on the Continent, the field magnets are inside the rotating armature, and the wires on the outside of the Gramme ring itself are bare, and act as the commutator.

The impossibility of starting the simple synchronizing motor with an alternating current will be of little consequence when a large amount of power has to be transmitted, seeing that in the receiving station there will be several sets of geared alternate current motors and direct current dynamos, some of which will be always running day and night. Hence, to start any alternate current motor, all that need be done will be to send round the direct current

[1] Continued from p. 546.

dynamo, attached to the motor to be started, a portion of the direct current that is being produced by one of the running dynamos. This will cause the stationary direct current dynamo to start running as a motor, and when the right speed has been attained—that is, when the motor is in step with the distant alternate current dynamo—the alternate current can be switched on to the alternate current motor.

Actual plans are being seriously got out at the present time, for using this exact method to transmit 5000 horse-power over forty miles in Tasmania, the received power being transformed by ten such combinations as are seen in Fig. 11, each of 500 horse-power.

This subdivision of the machinery at the receiving end, if accompanied by a similar subdivision of the generating plant at the sending end of the line, will have another most important advantage, viz. that a breakdown of a dynamo or of a motor will not cause a stoppage in the supply of power. A factory is, no doubt, worked at present with a single large engine; the propulsion of a steamer depends on the turning of a single powerful screw; but neither the unexpected stoppage of the factory engine for say half-an-hour once every two or three months, nor the delay of an Atlantic liner in mid-ocean for the same time once in every half-dozen voyages, would necessarily mean ruin. Were, however, the 10,000 horse-power dynamo at Deptford to be ever finished and worked at its full output, it would be necessary, in order to avoid a temporary hitch leading to the turning off the current from many thousands of glow lamps, and the plunging of a neighbourhood into darkness, to always have dynamos of a capacity of 10,000 horse-power kept idle in reserve.

Experience has shown that the size of each dynamo in a central station should be something like one-tenth of the maximum output, and that it is sufficient to keep one, or at the most two such dynamos, as a reserve, to prevent temporary breakdowns interfering with the steady supply of current. Until, then, a single central station is lighting some 500,000 glow lamps—or more than ten times the total number at present attached to the mains of the London Electric Supply Corporation—no one but the Brunel of electricity would have had the courage to embark on a 10,000 horse-power machine.

At any rate, when during the next year or two it is required to transmit a large amount of power over a considerable distance, it is probable that several alternate current synchronizing motors, each coupled to a direct current dynamo, will be employed at the receiving end of the line.

In cases, however, where there already exists an extended system of distributing alternate currents for electric light, the introduction of motors into small workshops and private houses will hardly be possible, unless the motors can be made self-starting. Mr. Zipernowski's motors, employed for driving the tools in a carpenter's shop at the Frankfort Exhibition, have been made self-starting, and also fairly efficient, by adopting a compromise between the simple direct current motor, which is self-starting but inefficient when used with alternating currents, and the alternate current synchronizing motor, which is efficient but not self-starting.

The device employed by Mr. Zipernowski, and which is based on a communication made by Prof. G. Forbes to the Royal Society of Edinburgh some eight years ago, is as follows:—Send the alternating current round the field magnet as well as round the armature of an alternate current motor (Fig. 10), and attach a commutator to the armature so as to reverse the current flowing round the field magnet every time the armature coils A_1, A_2, A_3 pass the field magnet coils M_1, M_2, M_3. On sending the alternate current round such a motor, the motor will start, but since at first the rapidity of alternation of the current will be far greater than the rapidity of commutation there will be much sparking at the commutator and waste of power. As, however, the armature turns more and more quickly, the commutation will be effected more and more rapidly, until at last the armature will attain such a speed that every time the current is reversed by the distant dynamo the portion of the current flowing round the field magnet of the motor will be commutated by the rapidly rotating armature. Hence the current flowing round this field magnet will now be always in the same direction. But as it will not be always of the same strength there will be more waste of power than with a simple synchronizing motor.

Such an arrangement as that adopted by Mr. Zipernowski, then, furnishes a motor which, although not as efficient and powerful for its weight as the synchronizing motor previously described, has the advantage of synchronizing fairly well, of being self-starting, and of giving far better results than a direct current motor with laminated field magnets used with alternating currents.

It is possible, however, as proved by Prof. Ferraris in 1885, to design an alternate current motor on totally different principles, and to construct a machine which will work not merely without a commutator, but without even any sort of rubbing contact. So that, in fact, the ends of all the wires on a Ferraris motor may be permanently soldered, and the motor left in the hands of a person who knows how to oil a machine but who is quite ignorant of the trimming and adjustment of the brushes of an ordinary direct current motor.

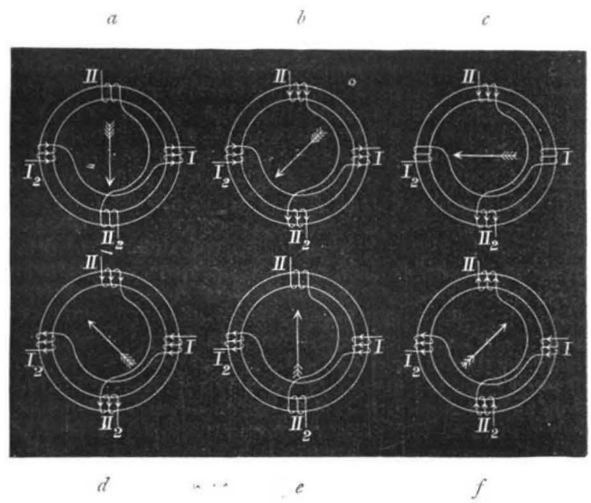

FIG. 12.—Rotating magnetic field produced by two alternating currents.

Round an iron ring are wound four coils, as seen in Fig. 12, and through the two distinct circuits are sent two harmonic alternating currents having the same periodic time and maximum amptitude, but differing by 90° in phase. The ring will therefore receive two magnetizations along two fixed diameters at right angles to one another, the two magnetizations alternating approximately according to the sine function of the time, and differing by 90° in phase. And the composition of these two magnetizations will give a "*rotating magnetic field*," which will make one complete rotation in the periodic time of alternation of the current.

Six values of these two currents are indicated in Fig. 12, the currents in *a*, *c*, and *e*, being of their maximum value in coils I, I_2, and nought in coils II, II_2; while in *b*, *d*, and *f*, the currents in the four coils are equal, being each $\frac{1}{\sqrt{2}}$ of the maximum value. The arrow indicates the position which in each case would be taken up by a suspended compass needle, the point of the arrow indicating the north-seeking pole of the compass needle.

If in place of the suspended compass needle there be a piece of copper, currents will be induced in this copper by the rotating magnetic field, tending to make the cylinder follow the field. Hence, if the copper take the form of a cylinder, with its axis coinciding with the axis of the ring, and supported so that it can rotate about this axis, the cylinder will run after the rotating field until it catches it up, when the two will move nearly synchronously together. On applying a resistance to the rotation of this cylinder—that is, on making the motor do work—the speed of the cylinder will be checked, but a small diminution of speed will cause large currents to be induced in the copper, and a pulling force to be exerted between the rotating field and the lagging cylinder, tending to drag the cylinder round. Hence this arrangement of Prof. Ferraris produces not merely a self-starting alternate current motor, but one which runs almost synchronously with the dynamo for wide variations in the load, and which has neither commutator, rubbing contacts, brushes, nor the possibility of sparking.

Within the past few weeks we have learnt that the idea of obtaining a rotating magnetic field was mentioned by M. Marcel Deprez, in a French patent dated May 1883. In that patent, when speaking of the magnetic field produced by the current flowing round a Gramme ring, he says: "*Cette rotation du champ magnétique peut être obtenue sans faire mouvoir aucune pièce; pour cela on fera naitre le champ à l aide de deux courants dont les points d'entrée sont sur deux diamètres perpendiculaires; l'aimentation de ce champ sera alors une résultante dont la position dépend des intensités relatives des deux courants, ainsi que cela a été décrit ci-dessus pour le comparateur des courants; il suffit de faire varier le rapport de ces intensités pour faire tourner cette résultante, et avec elle le champ magnétique.*"

It does not, however, appear to have occurred to M. Deprez that this rotation of a magnetic field might be employed to induce currents, and thus give motion to a piece of metal placed inside the Gramme ring; nor does he say anything about two harmonic alternate currents differing by 90° in phase producing the exact variation of current required. Although, then, what may be called the geometrical idea of producing a rotating magnetic field was certainly clearly described by M. Deprez, the credit of rediscovering this principle, and, what is far more important, of applying it in the design of the two-phase alternate current motor, is due to Prof. Ferraris.

To increase the strength of the rotating magnetic field, the copper cylinder originally used by Prof. Ferraris was next made hollow, and the interior filled with soft iron, the iron being laminated in planes at right angles to the axis, to prevent currents being induced in the iron; and to make the currents induced in the copper cylinder follow the most useful path the next step was to make a number of cuts through the hollow copper cylinder parallel to the axis of rotation. Practically, then, the rotating portion becomes a laminated cylinder of iron, on which is wound insulated wire parallel to the axis, as in a Siemens armature, but with this difference, that all the wires are electrically joined together at each end of the cylinder.

A two-phase alternate current motor was constructed and used by Prof. Ferraris in his laboratory at Turin in 1885. But not appreciating the practical importance of his own invention, and thinking that no motor requiring more than two wires could interest anyone but the natural philosopher, Prof. Ferraris occupied himself with attempts to utilize the rotatory magnetic field in measuring the resistance of conductors and with mathematical investigations on alternate currents. It was not, therefore, until the spring of 1888 that the results of his researches were published; when, a few months later, commercial motors based on exactly the same principles were brought ou[t] with considerable *éclat* by Mr. Tesla, of Pittsburg, who had been working independently in the same direction.

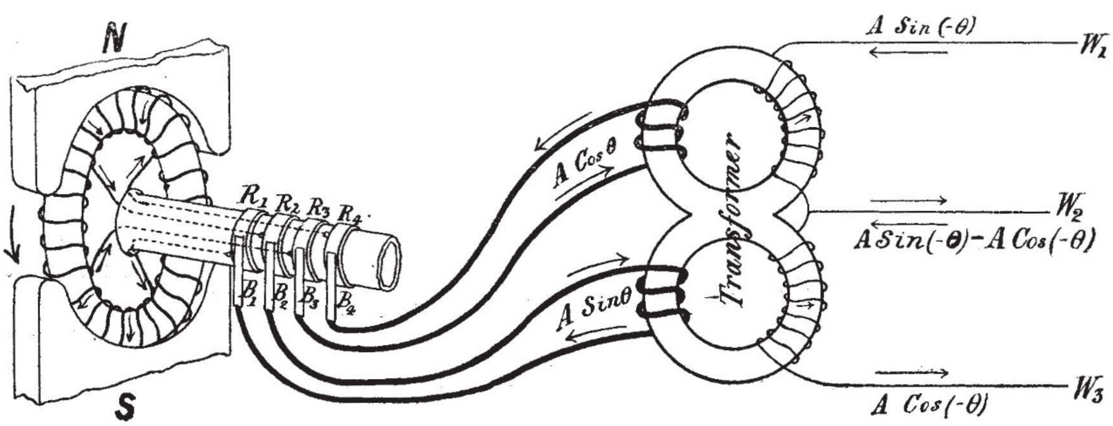

FIG. 13.—Schuckert two-phase alternate current generator and transformer. The arrows indicate the actual direction of the currents for the position of the armature shown.

To produce two alternate currents, differing by 90° in phase, the following device (Fig. 13) may be adopted, and is the one employed by Messrs. Schuckert in transmitting power at 2000 volts from the Palm Garden at Frankfort to the Exhibition, and by Messrs. Siemens and Halske for experiments on rotatory field alternate current motors in the Exhibition; the latter firm, however, not employing the special form of transformer shown symbolically in Fig. 13. In addition to the armature of a Gramme dynamo being joined up in the well-known way with the ordinary direct current commutator (this commutator and brushes rubbing on it not being shown in Fig. 13), four points at equal distances on the armature are permanently connected with four metal rings, R_1, R_2, R_3, and R_4, which rotate with the armature. Then it is easy to prove that while the machine is producing a direct current, used for exciting the field magnets as well as for any other purpose desired, the current passing through the wires attached to the brushes B_1, B_2, and the current passing through the wires attached to the brushes B_3, B_4, each alternate very nearly as the sine function of the time, the one reaching its maximum value when the other is nought.

The actual machine employed for this purpose by Messrs. Schuckert is the multipolar dynamo shown in Fig. 14, the direct current commutator and brushes, as well as the four rings and brushes for the two alternating currents, being here seen. If rotated mechanically, it will produce a direct current, as well as two alternating currents differing by 90° in phase; if supplied with a direct current, it will rotate as a motor generating the two alternate currents, and also doing mechanical work if required; lastly, if supplied with the two alternate currents, it will work as a two-phase alternate current motor generating a direct current, as well as doing mechanical work.

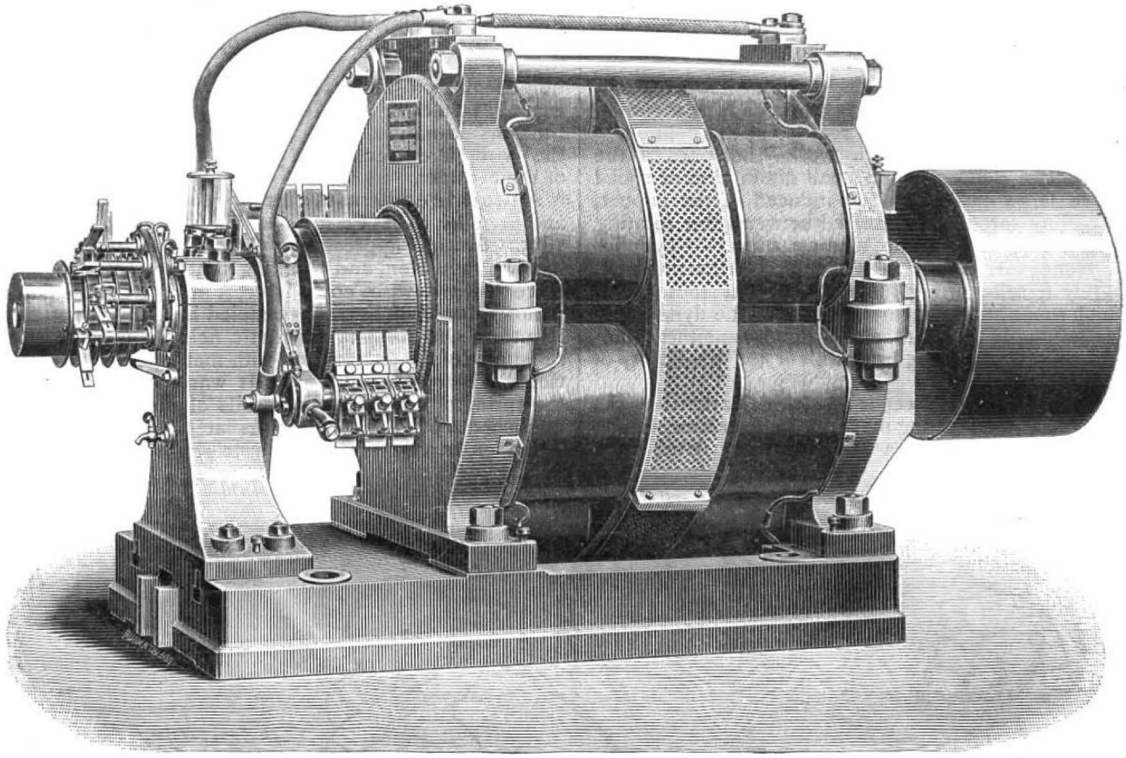

Fig. 14.—Schuckert's two-plane alternate current generator, or motor, or apparatus for transforming two alternate currents into a direct current.

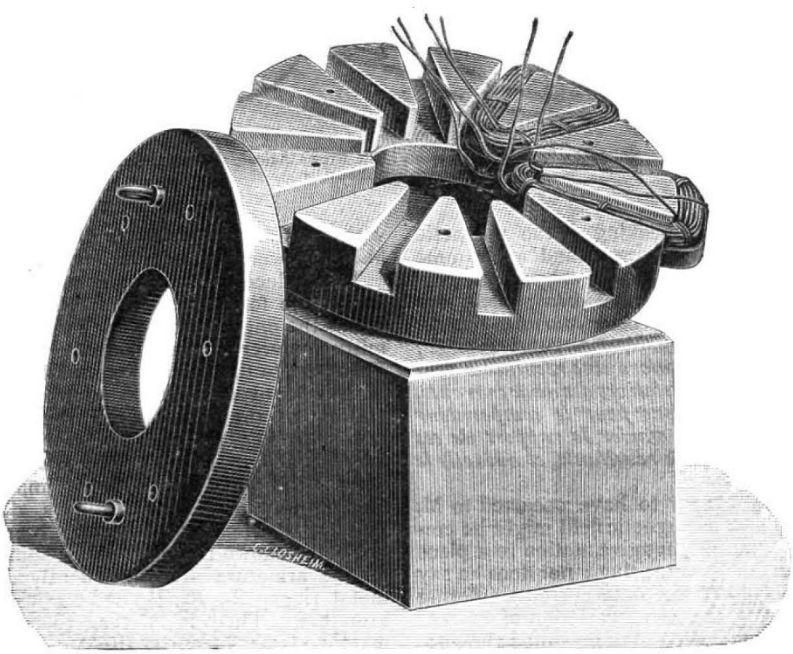

Fig. 15.—Schuckert two-phase alternate current transformer (method of construction).

When transmitting power to a distance, the two-phase alternate potential differences are transformed up from about 100 to 2000 volts; and to enable the transmission to be effected with three wires instead of four, Messrs. Schuckert arrange the transformer at each end of the line as shown symbolically in Fig. 13. Hence, if the currents produced by the dynamo be represented by A sin θ and A cos θ, the currents in the main wires, W_3, W_1, and W_2, will be represented by A cos $(-\theta)$, A sin $(-\theta)$, and A $\{\sin(-\theta) + \cos(-\theta)\}$ respectively.

The actual method employed by Messrs. Schuckert for winding this special transformer, as well as its appearance when completed, are seen from Figs. 15 and 16. This transformer, then, instead of consisting of merely a double ring of laminated iron as indicated in the symbolical diagram, Fig. 13, may be regarded as being composed of a connected series of laminated iron rings, each of a wedge-shaped cross-section.

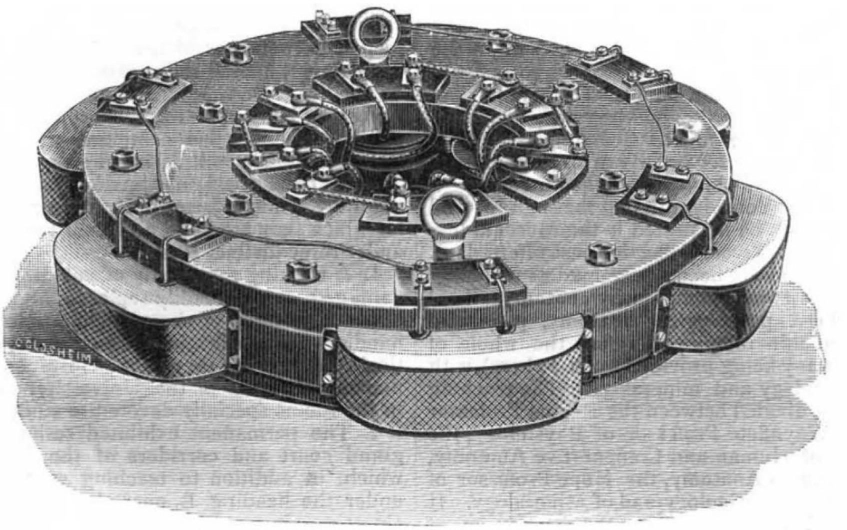

FIG. 16.—Schuckert two-phase alternate current transformer (completed).

(*To be continued.*)

THE OXFORD UNIVERSITY MUSEUM.[1]

THE following memorandum is based, not only upon observations made during a recent visit to Oxford, but also upon a fairly intimate knowledge of the origin and progress of the different departments of the Museum, acquired at various intervals of time extending over more than thirty years.

In entering upon the consideration of the subject which you have referred to me, it will first be necessary to define the purposes for which the Museum is maintained. These I take to be somewhat manifold, but they may be classed as follows:—

A. The first and main purpose is undoubtedly to assist in the educational work of the University, by illustrating the teaching of the professors and lecturers.

Besides this, however, it subserves, to a greater or less degree, other and what may be considered, as compared with the first, secondary, but nevertheless important functions. These are—

B. The exhibition of a collection, arranged in a systematic, orderly, and attractive manner, open to the inspection, under proper regulations, of all members of the University, and also of residents in and visitors to the town, which shall tend to awaken and keep up an interest in various subjects of which most educated persons, besides those actually engaged at the moment in obtaining instruction, desire to possess some knowledge. Such a collection is a most legitimate adjunct to the University as a place of general culture.

C. Certain collections have already, and possibly will in future, become added to the general Museum, the aim and scope of which reach beyond either of the above, being of value, not to the ordinary student, not to the man or woman of average general culture, but only to the advanced student who wishes to enter seriously into the pursuit of some special branch of knowledge. Such is the Hope Collection of Insects, and to a certain extent the Pitt-Rivers Ethnographical Collection.

It is a grave question how far such collections should be maintained at the cost of the University. On the one hand, they must be a cause of expense, without which no collection of any value can be maintained; and the larger and better ordered they are, the greater must be the cost of maintaining them. Unless properly cared for, not only as regards actual preservation of the objects contained in them, but also as regards the continual re-arrangements and augmentations necessitated by the advance of science, they will become comparatively valueless in the course of time. If the care of many such collections were undertaken unaccompanied by special endowments for their maintenance, the burden would become such as only a national institution could afford.

On the other hand, looking at the University, not merely as a place for the education of youth, but also as a centre of culture for the whole country, the possession of some such collections is of great importance. As they contain in them objects which can be found nowhere else, they attract men of learning and science, not only from other parts of the country, but also from distant places, to visit the University, or even to become permanent residents. The value of collections of rare books, even upon subjects interesting to scholars whose numbers are very limited, have long been recognized. From the same point of view, special collections of rare specimens of natural history or works of art may take their place in the general scheme of a University Museum, but the care of such collections should not be undertaken without full con-

[1] Prof. Flower's Report to the Committee on Collections appointed by the Delegates of the University Museum, Oxford, dated March 14, 1891.