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Evolution of the Dynamo

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Several years ago when men spoke in jest of encircling the earth in forty minutes, they had no idea that such a feat would ever be possible; but what would they say if they were to come back for another look at this world and see the thing actually accomplished?

Their first act would be to inquire what great discoveries or inventions had led to such an advance from their time; and they would be answered, "It is all due to the discovery of the power of electricity." "Who made this great discovery ?", they would ask, and we should answer that in the year 600 B. C. Thales a scholar of Miletus in Asia Minor, accidentally found that after rubbing a piece of amber against his clothing, it first attracted and then repelled light objects when they were brought near it. But as he could not explain this action of the amber, no historical mention was made of electrical phenomena until the time of Theophrastus (341 B. C.), who wrote that amber when rubbed attracted straws, small sticks and even thin pieces of copper and iron. Both Aristotle and Pliny speak of the electric eel and its power to benumb other animals which come in contact with it.

Thus far only simple phenomena had been mentioned and no study of the electrical force had been made. This seems rather strange to us, when we consider the culture and power to investigate of the ancient Phoenicians, Egyptians, Greeks, and Romans. True we find in their literature certain stories of people being cured of disease by shocks from the electric eels; but further than this they make no mention of electricity. Even in the Middle Ages when writers and scientists saw fit to speak of the electrical phenomena observed by the ancients, they failed to follow up the study and made no additions to the science.

It was not until after a lapse of two thousand years from the discovery of Thales that Dr. Gilbert, physician to Queen Elizabeth, took up the study of amber and other substances which when subjected to friction acquired the power first to attrack then to repel other objects. He published his observations o in a little book called "De Magnetism" in the year 1600 A. D. and thus became the first author upon electricity. For many years after this, electrical experiments were carried on upon the lines laid down by Dr. Gilbert: and the substances which obtained the power of attracting other bodies, came to be known as electrics.

Among the ablest investigators at this time Robert Boyle, author of "Experiments on the Origin of Electricity", Sir Isaac Newton, Otto von Guericke, and Francis Hawksbee, the last of whom communicated his experiments to the English Royal Society in 1705. Of the above probably Newton and Hawksbee conducted experiments of the most value. They used a glass globe, and caused it to revolve rapidly while rubbing it with the hand; thus they became the originators of the better equipped electrical machines now used for school purposes.

The next step of importance and one which marks an epoch in the science was taken by Stephen Grey of England in 1729. To him is due the discovery that the electricity from the glass cylinder could be carried some distance; and though he used only a pack-thread for a conductor, he succeeded in transmitting electricity several hundred feet. From experiments of this kind came the knowledge that some substances were natural conductors while others were practically non-conductors and that the substances which were non-conductors were those generally known as electrics.

Another important step was soon taken. Previously the only way to get electricity for experiments had been by means of the glass ball or wheel, but now a discovery was made by which the electricity from the glass ball could be bottled up and then drawn upon for experimental purposes. It is not known who made this important discovery, but the name given to the storage apparatus was leyden jar, from Leyden, a city in Holland.

About this time there appeared a man whose writings and experiments had more to do with systematizing the science and turning it to practical use than any of his comtemporaries. This was Benjamin Franklin of Philadelphia.

In 1790 Galvani of Bologna, Italy, discovered while experimenting upon a frog that alternating motion between the nerves and muscles could be produced by a force generated by certain dissimilar metals when brought together. Though this came to be known as the galvanic fluid and galvanism was made to perpetuate his name, it was not until 1800 that Volta, another Italian, succeeded in proving to the world that a new force had been discovered. Volta constructed what became known as the galvanic pile, but more largely since as the voltaic pile, which he found would generate electricity strongly and continuously.

In 1801, Nicholson showed that when electricity from a voltaic pile was passed through salt water, the water was decomposed into hydrogen and oxygen.

In 1807 Sir Humphrey Davy still farther applied electricity to chemistry and demonstrated that substances in the earth's surface heretofore known as elements could easily be resolved into their components by a strong current. Two years later, in 1809, he made a discovery that was phenomenal. He showed that if an electric current was passed through two pieces of carbon when the carbons were separated a little way the spark passing between them gave a very intense light. This was the discovery of the principle of the electric arc light which is used to-day in every city of the world.

Between 1819 and 1830 many important laws governing electrical phenomena were formulated. Orsted of Denmark ascertained the means of measuring the strength and direction of a current; Ampere of France, the identity of electricty and what before had been called galvanism. Ritchie of England made the first machine by which a continuous motion was produced by the attraction and repulsion between fixed magnets and electro-magnets. This machine was a suggestion of the present dynamos and motors.

It was not until 1831, when Faraday began to make his splendid experiments, that an exhaustless spring of electricity was found. His prime discovery was that of the induction of electric currents or manufacturing electricity directly from magnetism. The induction coil used by Faraday, though crude in form, embraced the same principles as the coil employed to-day. It consisted of an iron core about which were wrapped two layers of insulated wire. One layer consists of a thick, short wire and is called the primary coil, while the other is a very long, thin wire known as the secondary coil. When an electric current is passed through the primary coil with freqrent breaks, it induces an alternating current of very high tension in the secondary coil, thus powerfully increasing its effects.

Among Faraday's other inventions was a dynamo which he produced about this time. It was simply a copper disc revolved between the poles of a magnet. When the disc was revolved, it was found that by connecting two wires by means of springs - one to the axle and the other to the edge of the disc - a current was produced which flowed from the axle to the edge fo the disc and then around through a wire bach to the alxe again.

One of the simpliest forms of an electric machine is the magneto. It consists of a simple turn of wire the ends of which are connected to two rings called commutator rings, and arranged so as to revolve between the poles of a magnet. Resting on each commutator ring is a metallic spring or brush which server to conduct the current away from the machine into the external circuit. A machine of this type will produce an alternating current; i.e., a current which during one half of the revolution rises from zero to its maximum value and then falls back to zero again, and during the other half of the revolution goes from zero to its maximum value below the line and then rises to zero once more.

There is another machine similar to the above only it gives a continuous current; i.e., a current which never falls below the zero line, and the only difference between these two machines is in the commutator rings. In the alternator there are two rings while in the continuous current machine there is only one ring; but this is made up of a number of segments insulated from each other, and the wires of the armature are connected with these different segments.

In all dynamo-electric machines there are three principal parts; 1st, the inductors, or magnets, by which the field is excited; 2nd, the armature or conducting system in which the E.M.F. is generated; and 3rd, the brushes or conductors through which the current is taken away from the machine.

All dynamos are divided into two classesand in the classification there are three points which must be noticed: 1st, Is the E.M.F. induced in the inductors as it rotates, always in the same direction or does it alternate by reason of cutting the same lines of force twice in the same revolution but in opposite directions ? 2nd, Is the length of the inductor parallel or at right angles to the axis of revolution ? 3rd, Is the external E.M.F. alternating or continuous ?

The two classes of dynamos are first those in which the inductors cut the same lines of force twice, but in opposite directions, in the same revolution, and by reason of so cutting them have an alternating E.M.F. induced in them. They are called bi- or multi-polar dynamos. Secondly, those in which each inductor when cutting lines of force always cuts them im the same direction and therefore the E.M.F. induced is a continuous one. Such machines are called uni-polar dynamos.

We will first take up the discussion of the dynamos which belong to the former class and in which the inductor's length is parallel to the axis of rotation.

Through the center of a rectangular gap formed in a horse-shoe magnet by letting the poles have plane sides, let a spindle which has a wire raidly some distance from it but supported upon it at each end be placed. Now when the spindle is rotated, the wire will cut the lines of force first in one direction and then in the opposite and this will induce an alternating E.M.F. in the wire. If the ends of the wire be connected with a pair of connecting rings on the spindle but insulated from it, against which two other wires are connected by means of springs, we shall have a machine which is giving off an alternating E.M.F. One of the disadvantages noticed about this machine is the long air gap through which the lines of force are compelled to pass. This gap can be greatly diminished by boring out the sides of the magnet, so that they will more nearly conform to the shape of the armature; but this is found to help us but partially, as now the greater part of the lines will jump across at the edges where the air gap is least and the only remedy found for this disadvantage is to make an iron cylinder which is placed between the poles of the magnet. The inductors may be laid upon this core if we wish. It will now be seen that instead of jumping across at the edges, the lines of force will all crowd through the iron core as it forms the path of least resistance between the poles, thus making more lines than can be cut by the inductors and consequently generating a larger E.M.F. This iron cylinder when used as a core for the armature needs to be rotated, although it is entirely unnecessary on any other ground.

We will now pass to the dynamo of the second class, or those in which each inductor when cutting lines of force, is always at any movement in the revolution cutting them in the same direction and further never cuts any lines twice in the same revolution, hence the E.M.F. generated in each inductor always has the same direction along its length and is never reversed. This class of dynamos may be divided into two groups: 1st, those in which the inductor's active length is parallel to the axis of rotation and 2nd, those in which they are at rigth angles to the axis of rotation.

In the first group consider a single inductor rotated between two curved pole pieces: the E.M.F. generated will always be in the same direction along the inductor's length and will last as long as the inductor is moving through the field. Now if the field magnets be made tubular, there will be no break in the E.M.F. which will be maintained continuously and at a constant value, and if the circuit be completed by joining the ends of the inductors by rubbing contacts with an external circuit, we shall have a uni-polar dynamo giving a continuous current both externally and within the armature itself.

In the second where the inductors length is at right angles to the axis of rotation, it is simplier to mount the field magnets upon the spindle, thus making them the revolving part and letting the armature remain stationary.

So far in speaking of dynamos we have had only one inductor; but it is found that in order to obtain an E.M.F. that is large enough to use, we must have several inductors joined in series and these inductors may all be laid upon the same core. Two methods of adding the inductive actions of a pair or more of inductors at once present themselves. By the first inductor No.1 is connected in series with another inductor, No. 2, next to it on the surface of the core and under the same pole piece. By the second method the first inductor is connected with another nearly diametrically opposite on the other side of the core.

The former or "ring" method was first employed by Prof. Pacinotti of Pisca in 1864, but it is also frequently called the "Gramme" winding from a French electrician of that name, who independently discovered and introduced it again seven years later in 1870. The principle of this type of armature is a soft iron ring around which is wound insulated copper wire, which is connected at regular intervals with the segments of the commutator. In this type of armature the turns of wire are laid side by side on the core. The only difference between the armatures invented by Pacinotti and Gramme is found in the core. In that of Pacinotti there are a number of teeth on the surface of the ring and the wire is wound between these teeth to keep it from slipping; while in the Gramme armature, the core is a smooth iron ring with the wire around it. Now we can see more plainly the advantage of an iron core between the poles of the magnet. If it were not for this core, the lines of force would pass directly across from pole to pole, and there the portion of the wire that was inside of the ring would be cutting lines of force the same as those on the outside, and this would set up two E.M.F!s opposite each other; whereas if the iron core is used, the lines all pass through it, and in this way only the portion of the wire on the outside of the ring cuts lines of force and generates an E.M.F.

The second, or "drum" method is identified with the name of Siemesis, but it was not introduced in its complete form until 1873, then by Von Hefner Alteneck. This form is even simpler than the ring, and consists in joining the further end of one inductor by a connecting piece of wire across the end of the core to the further end of another inductor situated nearly diametrically opposite the first. The E.M.F. induced in the two inductors will now help each other around the loop thus formed, being in opposite directions along the loop as viewed from the end.

From what has been said the technical points in the construction of the dynamo are now evident. The different types and practical use of dynamos will now be considered.

First there are dynamos which are designed for a constant current and a high E.M.F. These machines are used for arc lighting and are made for a high potential so as to be able to run several arc lights in series and thus save considerable expense in wiring. Other machines are built to give a low E.M.F. and a large amount of current; and such machines are used for electro-plating, where it is desirable to deposit the metal upon the object slowly, and where a high E.M.F. would be detrimental. Still other machines are built with an E.M.F. and current of medium value, and are used for incandescent lighting, where the amount of current depends upon the number of lamps, but the voltage is the same no matter whether you are lighting one lamp or one hundred. And then we have machines for the generation of an alternating current, which is used for lighting purposes; but generally it is transformed and applied to run motors situated at considerable distance from the station. More often instead of running an alternator, current is taken from a continuous machine and then put through a rotary transformer, where it is changed to an alternating current and stepped up to ten thousand volts, transmitted thence to the suburban station, where it is again transformed to a continuous current of five hundred volts for running electric cars and motorw. These motors may in turn be used to run arc light machines or other dynamos.

It will be well for us to note of what vast importance electricity is to a community. The introduction of electric lights into a village has much to do with the growth of the place, as having the streets well lighted insured the safety of the people when they are out at night, and so they will not be afraid to move into the village. Then let us consider the electric car. A few years ago electric car lines save outside the cities were not even thought of; but now we hear talk of great suburdan lines, and doubtless within the next few years all our large towns and cities will be connected by electricity. Some of us may even live to see the day when the old steam road will be crowded out and the electric railway take its place.

Lastly, let us look at the automobile, that new field to which electricity may be applied with even better results than any other motive power known at the present time. The automobile is a new thing and is still in the experimental stage; but it is fast improving; and in the future we may expect to see it displace the horse to a considerable extent.