

Course Name: Design of Electric Motors

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Title: History Prospect of Electrical Machines

Greetings to all of you, this is the first class and in this class, we will discuss history prospective of electrical machines. The first electric motor is invented by Andrew Gordon and Benjamin Franklin in 1740. This motor works on the principles of attractions and repulsions of electric charges. The conventional magnetic machines will be attractions and repulsions of magnets. Here, the electrostatic motor works on the attractions and repulsions of electric charges, just dual to the magnetic machines, but this is the motor which was invented initially that is in 1740. Andrew Gordon and Benjamin Franklin did the experiment with high voltage DC as an input.

This high voltage DC is generated with Van De Graaff generators. At present, we can generate with simple power converters like rectifiers and DC-DC converters and etc. This high voltage DC positive is connected to the one end of the stator like this side. This is the one electrode of the stator which is connected to the positive and other side, other electrode of a stator is connected to the negative side of the supply.

Rotor also consists of electrodes like four electrodes it has and the nearest rotor electrode with respect to the stator electrode will be ionized or it is positively charged. Similarly, at the negative side, the electrode near to the stator negatively charged electrode will be as a negatively charged one and depends upon the attractions and repulsions of these charges. This motor will work and the direction of the rotation depends upon the placement and angle of the electrodes on the rotor or we can use the Fleming's left hand rule with duality to get the direction of rotation. And this kind of machines, we are utilizing in micro electro-mechanical systems like micro electro static actuators. Christian Orsted discovered the relation between the electricity and magnetism in 1820.

He did the experiment with current carrying conductor and magnetic needles. In this experiment, he observed that the deflection in the magnetic needle when the current is

flowing through the conductor that we can observe in this animation. As per the thumb rule, like the thumb represents the current and the fingers represents the magnetic fields. So, as per this thumb rule or corkscrew rule, we can identify the flux directions and because of this current carrying conductor, the deflection in magnetic needle is happening here. This Orsted invention gives the direction to explore the revolutionary things with respect to Faraday's, Ampere's and Tesla and Maxwell and other inventors.

After that in 1820, Ampere invented the first solenoid. Based upon the principles of Astar, he did the experiment with solenoid where the multiple coils he connected or conductors connected in series to make the coil. He presented the magnetic field with respect to the solenoid or the magnetic field is enhanced with respect to the single conductor. He also proposed or invented a Ampere's law where the Ampere's law gives the relation between the magnetic field and current which is acting as a source of it. The in detail about the Ampere's law, we will discuss in the coming lectures.

In 1825, William Sturgeon invented the electromagnet. First electromagnet is invented in 1825. What he did is based on the invention of Ampere in order to increase the magnetic field or in order to enhance the magnetic field, he just introduced an iron core that is here shown as in green color. We can observe from this figure. The iron core will give the less resistance for the magnetic fields whereas, free air in the Ampere's invention gives the more resistance for the magnetic field that is the difference between the Ampere's and Sturgeon's invention.

So, if we will see the equation at the right hand side, B equals to $\mu_0 \mu_r n I$. Here, μ_r is the relative permeability of the core which will enhance the magnetic field that is the invention. The actual setup with respect to the electromagnet, we can see in this image and this is the simplified electromagnet. And next in 1821, Michael Faraday invented the first electromagnetic motor that is called as a homopolar motor also. When a current carrying conductor placed in a magnetic field, it experiences a force.

So, he concluded from his experiment this thing. And in 18 same year, he presented the principles of electromagnetic induction also. The pictures showing at the right side, this one as well as this one are the actual experiment setup with respect to the Michael Faraday. And this is the simplified setup. Here, we can see that battery is the source and the current is flowing through the coil copper wire and after that this is the blue color one is the rod and through the salt water or mercury and then the electrode, the black color one is the electrode and flowing back to the source and the green color one is the magnet.

So, the current carrying conductor will exhibit the magnetic field. So, that magnetic field is source one and the other source is the green color one permanent magnet. So, based upon the attractions and repulsion, it will experience a force in an orbitary or circular manner around the magnet. That is the direction is shown in the blue color dotted one here. And after that in 1828, Z.

Leak and in 1833, William Sturgeon are proposed to the or invented the first commutated rotating electrical mission. Even though Z. Leek is the first inventor of the first commutated rotating machine, their inventions are not documented, but William Sturgeon parallelly did the research and documented about the first commutated rotating electrical machine in 1833. As per the Z. Leek experiment, we can see the image at the left hand side and this is the coil one, simplified coil one that is stator stationary part and the coil two which is rotating part.

Here, we can see that coils are distributed and the commutator is there in between and as per the Orsted's principles as well as Thumb's rule, we can see the flux lines are flowing in this manner with respect to the direction here and the current flowing in this manner and coming back like this. Similarly, here also as per the same Thumb rule, the current is entering into the coil and the magnetic field in this direction. So, the first coil if you will consider which is thumb is indicating the magnetic field and current is flowing in this manner fingers. Just I am considering in a opposite manner. The second coil Thumb rule will be thumb indicating the current and flux lines are represented by fingers.

Now, you consider in a opposite manner and then you will get this thing. Similarly, here also just for easy understanding the coil one which is stationary, I am representing with the magnetic poles north and south and the second one the coil which is rotating along with the commutators, we can have represented in this manner. So, based upon the attraction between the opposite poles north and south and repulsion between the same poles, we can see here and based on that principle, the rotor is rotating or this complete coil set is rotating. Once the coil two reached this position or instant two, here south and north in the attraction mode and bottom side also south and north in the attraction mode, there is a magnetic locking. Further there is no rotation to make the continuous rotation here the commutators, the blue color one the commutators will change the current direction flowing through the these two coils.

Then the poles will be reversed, then again repulsions and attractions will happen. So, motor will rotate continuously. This is the principle of DC motor. The first invention related to the electromagnetic machines done by the William Sturgeon, we can see in this slide. After that huge research happened from 1832 to 1890.

In 1832, the first AC current generator is invented by Hippolyte Pixie where he did the experiment with permanent magnet by rotating with a hand crank over a coil will induce

a current in that coil. That is the first AC generated invented in the year 1832. After that Walter Bailey invented the first manual switching induction motor in 1879. Instead of commutators, he manually switched the coil excitations and he invented the manual switching AC induction motor. Later in 1885 to 1889 and 1889 to 1990, the Nicholas Tesla, Galileo Ferraris and Mikhail Dolivo invented the induction motors.

The first induction motor proposed by or invented by Nicholas Tesla and Galileo Ferris that relies on two phase induction motors which works on the principles of mutual induction with respect to the faraday's laws. In 1890, the same machine is updated with three phase cage as well as squirrel cage induction motors by Michael Delevaux. The principles of induction motor is simple and same as the DC motors, but the rotor and stator are interchanged now. Earlier this coil was acting as a stator. Now, this coil is acting as a rotor.

It is rotating and it is a closed conductor and stator side, we have a two coils and we are applying with AC supply. So, as per the thumb rule, we can get the magnetic field distribution at the stator coils as well as the rotor coil. Like stator coils as per the thumb rule, the current is entering where the current I am representing with the fingers and the flux lines in this direction and in the rotor side same way as per the current direction, we can say that at the top side, you see the current is flowing from left to right. So, you consider the thumb rule in this direction opposite to me may be. Then, you will see the flux lines are coming from top to bottom and the pole representation I have shown at the left side corner and the stator side, we have the south and north pole combination and the stator side north and south based upon the attractions and repulsion motor is working.

After this instant, the next instant will happen in this manner like where south and north as well as right side south and north will form a magnetic locking. So, because of the AC supply to the stator coils, automatically the poles will be changed to this instant. So, again the north and north will repel each other and south and south will repel each other. The direction of rotation will be identified by utilizing the Fleming's left hand rule. So, this is the principle of induction motor or I can say that based upon the AC supply excitation, there is a rotating magnetic field at the stator core and this rotating magnetic field will link to the squirrel cage or closed coils at the rotor side.

There is an induced current because of this induced currents, there is a magnetic fields at the rotor side. The interaction of these two fields will create the force that is the principle of induction motor. And based upon the inventions like after this 1890 also huge inventions happened at present also lot of research is going on the in the area of electrical machines. These are the few machines as of now the presented machines, the DC motors and AC motors and other type of motors with respect to the electromagnetic type and other type will be electrostatic and then static machines or transformers. And in the DC motor type wound field in that category series shunt compound and separately

excited and instead of wound field permanent magnet field excitation also we can utilize it.

This is a permanent magnet type of DC motors and in the AC motors synchronous, asynchronous and reluctance machines. And in the other type of motors, we can see universal motors which works on both AC as well as DC servo motors and vernier permanent magnet motors and hybrid motors and etc. Thank you this is the history prospective of the electrical machines.