PERMANENT-MAGNET ROTARY MOTORS

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Abstract. *Different types of traction motors (DC, asynchronous, valve with excitation from permanent magnets) are compared. It is demonstrated that a valve motor with excitation from permanent magnets is the most suitable for using in electric vehicles and electric buses.*
Keywords: *electric vehicle, valve electric drive, asynchronous electric drive, synchronous drive*

Introduction

Every day our planet is exposed to the terrible effects of greenhouse gases produced by autos with internal combustion engines.

Electromobiles are environmentally friendly analogues of gas engine autos with electric motor. They work without usual fuel like diesel fuel or gasoline instead of using clean and renewable electricity energy.

The electric vehicles popularity in Russia is growing: sales of new cars have increased by 30%, and second-hand ones - by 70%.

In autumn 2017 the Moscow City Hall announced a tender for the purchase of electric buses for using as the city public transport. The city authorities are ready to purchase up to 300 such vehicles.

An electric car has a number of undeniable advantages: the absence of exhaust gases that harm the environment and living organisms, low operating costs (since electricity is much cheaper than automobile fuel), high efficiency of the electric motor (90-95% while the efficiency of the gasoline engine is only 22-42 %), high reliability and durability, simplicity design, possibility of recharging from an ordinary outlet, low explosion hazard in accidents, high ride smoothness.

The most important part of the electric vehicle is the electric motor.

The paper purpose is to compare different types of traction electric motor (DC, asynchronous, valve with excitation from permanent magnets) and choose the best option for using in an electric vehicle.

Materials and methods

In some cases DC motors are still indispensable, since they have a large overload capacity, good starting and adjusting properties. However, they have significant drawbacks, which are due to the presence in the DC motors of the brush-collector unit, which is also a source of radio interference and fire hazard.

AC motors does not have these drawbacks. These traction electric drives (both asynchronous and synchronous) prove to be more reliable, lightweight and durable, even despite the fact that they have more complicated and expensive regulation system of the traction electric drive.

The disadvantage of asynchronous alternating current machines is that their windings are distributed over many slots in the stator core. This leads to the occurrence of the long end turns, which increase the dimensions and energy losses in the machine.

Permanent magnet synchronous motor (PMSM) is a synchronous electric motor, the inductor of which consists of permanent magnets.

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PMSM advantages are:

- Valve electric motors have higher efficiency (up to 92%), which allows them to be used in cases where energy saving is required
- high efficiency of the valve motors allows increasing their operation time in several times from an autonomous power source
- replacing asynchronous motors with Valve Electromotor in intelligent systems makes significant energy savings possible due to the adjustment of the rotation rate in the range 20 ÷ 100% of the nominal value while maintaining the maximum performance (momentum, efficiency)
- more stable momentum, vibrations absence and minimal acoustic noise while operating on all modes allows provideing much more comfortable living conditions when used in household devices
- heat dissipation in the developed valve motors is 2 times less than in serial asynchronous motors of the same power, with significantly smaller weight and size parameters
- valve electric motors have a high momentum value in a wide range of rotation rate
- significantly better mass and size characteristics in comparison with electric motors of similar capacity. [2]

A control system, for example, a frequency converter or a servo drive, is required for synchronous motor with permanent magnets to work. In this case, there are a large number of ways to manage the implemented control systems. The selection of the optimal control method mainly depends on the task that is put before the electric drive. The main methods of controlling a synchronous electric motor with permanent magnets are given in the table below.

Trapezoidal control using Hall sensors (for example computer fans) is usually used to solve simple problems. A field-oriented control is usually selected to solve problems that require maximum performance from the electric drive. [3]

Various types of magnets can be used in permanent magnet electric motors: Samarium-cobalt (SmCo) and neodymium-iron-boron (NdFeB).

Advantages of SmCo magnets include high residual magnetization Br (up to 11.5 kg), coercive force Hci (from 5.5 to 25 kOe) and high Curie temperature. The disadvantages of SmCo magnets are their high cost and fragility. This is the most expensive of the available magnetic materials.

NdFeB magnets have a wide range of operating temperatures (from -40 ^{0}C to +150 ^{0}C), some of them can be used up to 200 ^{0}C. Modified magnets can be used up to +220 ^{0}C. Exposure to corrosion of NdFeB forces the coating to be applied to the magnets.

It is economically expedient to use magnets NdFeB. [1]

Main methods of controlling a synchronous electric motor with permanent magnets

<table>
<tr><th colspan="4">Control</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td rowspan="4">Sinusoidal</td><td colspan="3">Scalar</td><td>Simple control scheme</td><td>Control is not optimal, not suitable for tasks where the load varies, the controllability loss is possible</td></tr>
<tr><td rowspan="3">Vector</td><td rowspan="2">Pole-Oriented control</td><td>With position senser</td><td>Smooth and precise positioning of the rotor and engine rate, large adjustment range</td><td>Requires a rotor position sensor and a powerful microcontroller control system</td></tr>
<tr><td>Without position senser</td><td>No rotor position sensor is required. Smooth and precise positioning of the rotor and engine rate, large adjustment range, but smaller than with the position sensor</td><td>Sensorless field-oriented control over the entire speed range is only possible for Valve Electromotor with a rotor with clearly defined poles, a powerful control system</td></tr>
<tr><td colspan="2">Direct momentum control</td><td>Simple control scheme, good dynamic characteristics, large adjustment range, no rotor position sensor required</td><td>High ripple of momentum and current</td></tr>
<tr><td rowspan="3">Trapezoidal</td><td colspan="3">Without closed-loop</td><td>Simple control scheme</td><td>Control is not optimal, not suitable for tasks where the load varies, loss of controllability is possible</td></tr>
<tr><td rowspan="2">Closed-loop</td><td colspan="2">With position sensor (Hall sensors)</td><td>Simple control scheme</td><td>Hall sensors are required. There are moment pulsations. Designed to control the Valve Electromotor with trapezoidal feedback EMF, when controlling the Valve Electromotor with a sinusoidal inverse EMF, the average moment is lower by 5%.</td></tr>
<tr><td colspan="2">Without position sensor</td><td>Requires a more powerful control scheme</td><td>Not suitable for low speed operation. There are moment pulsations. Designed to control the Valve Electromotor with trapezoidal feedback EMF, when controlling the Valve Electromotor with a sinusoidal inverse EMF, the average moment is lower by 5%.</td></tr>
</table>

Results

The main comparative characteristics of traction motors: asynchronous, valve and DC

<table>
<tr><td rowspan="2">Parameters</td><td colspan="2">Type of traction motor</td></tr>
<tr><td>Asynchronous</td><td>Permanent magnet synchronous motor</td></tr>
<tr><td>Max. power, kWt</td><td>160</td><td>160</td></tr>
<tr><td>Rated current, A</td><td>279</td><td>210</td></tr>
<tr><td>Rotational speed, rpm
• rated
• max</td><td>
1500
3000</td><td>
1500
3500</td></tr>
<tr><td>Weight of electric motor, kg</td><td>945</td><td>350</td></tr>
<tr><td>Efficiency, %</td><td>90</td><td>94,6</td></tr>
<tr><td>Overall dimensions, mm</td><td>1185x845x645</td><td>510x510x500</td></tr>
</table>

Comparison of different types of traction motors (DC, asynchronous, valve with excitation from permanent magnets) shows that the most promising is a traction valve motor with excitation from permanent magnets, which is 1,5 ... 2,5 times lighter, has the highest efficiency and the best adjusting characteristics. In the electric transport it is very important to have a low weight, and a stock of spare space for the installation of batteries.

References

1. Lokhin V.V. Non-contact traction electric motor in the valve electric drive structure // Collection of scientific papers “Electromechanical systems” / edited by A.V. Lepeshkina. – Moscow: Moscow Polytechnic University “MAMI”, 1995. – P. 38–43
2. Ovchinnikov I.V. Valve electric motors and drive based on them (low and medium power) [Text] / I.V. Ovchinnikov. – St. Perersburg: Korona-vek, 2006. – 336 p.
3. Sokolovsky G.G. Electric drives of alternative current with frequency control: College book [Text] / G.G. Sokolovsky. – Moscow: “Academia” publishing center, 2007. – 272 p.