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Analyzing the axial flux permanent magnet synchronous motor operates above the nominal speed

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Abstract: *In terms of structure, the AFPM motor has its own particular specialists, in details, the stator module may include several types: A single module has one winding set and a dual module has two sets of winding sharing a common core and back-to-back establishment. Similarly, a single rotor module includes only one permanent magnet on one side, and in dual module one, both sides have permanent magnets leaning against each other. Analyzing the working mode of the AFPM motor is essential in modeling and designing the control of the system.*

Keywords: *AFPM motor, speed controller, axial position.*

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I. INTRODUCTION

Axial flux permanent magnet motor (AFPM) finds its important role in electric drive systems [1]. Thanks to the ability of producing torque and force at the same time, AFPM does not require axial bearings that my cause mechanical problems [2]. The axial flux motors are one of the most promising electric drive technologies due to its high-power density. Recent researches target mainly on the design problem of AFPM [3-10], very limited number of works looking at control aspect [11-13]. Most of the works done on control of AFPM use linear control technique that may result in limited operating range of the motor.

II. MATHEMATICAL MODEL OF THE AFPM MOTOR

When a three-phase voltage is granted to stator coils, different currents are generated (including current i_q) flowing inside, they will interact with the magnetics of rotor to generate torque (M) and the currents in phase windings (component i_d) of stator generate thrust and drag (F) based on the principle of the electromagnet. Thanks to special structure and above-mentioned operating principle, the rotor of the motor will not generate axial displacement although both ends of the shaft have magnetic bearings. It allows the absence of additional axial movement block of the rotor, therefore, the motor structure is being compact. Due to the way of winding roll, the rotational magnetic field generates torques M_1 and M_2 on the same direction on the rotor shaft and generates thrust-drag forces *F1* and *F2* between the rotor and the stator on opposite direction. The total torque ($M=M_1+M_2$) is the summation of the torques but the total force is the difference of the axial attractive forces ($F=F_1-F_2$).

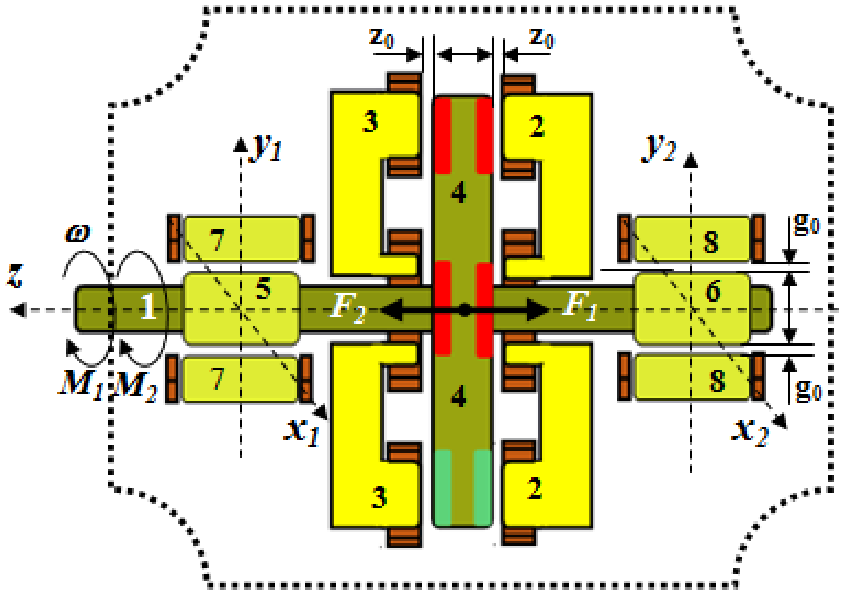

***Figure 1**: The AFPM motor section with magnetic bearing at both ends integrated*

From the structure and the principle of operation mentioned above, AFPM motor can be considered as two motors that have a common rotor or share a common sharp.

The mathematical model of AFPM motor was developed in *dq* coordinate system, as presented on (1). The indicator 1 and 2 are present for the left side motor and right side motor, respectively.

$$\begin{cases} u_{sd1}=R_s i_{sd1}+L_{sd1}\dfrac{di_{sd1}}{dt}-\omega_s L_{sq1} i_{sq1} \\ u_{sq1}=R_s i_{sq1}+L_{sq1}\dfrac{di_{sq1}}{dt}+\omega_s L_{sd1} i_{sd1}+\omega_s \psi_p \\ u_{sd2}=R_s i_{sd2}+L_{sd2}\dfrac{di_{sd2}}{dt}-\omega_s L_{sq2} i_{sq2} \\ u_{sq2}=R_s i_{sq2}+L_{sq2}\dfrac{di_{sq2}}{dt}+\omega_s L_{sd2} i_{sd2}+\omega_s \psi_p \\ m_{M1}=\dfrac{3}{2} z_p \left[\psi_p i_{sq1}+i_{sd1} i_{sq1}(L_{sd1}-L_{sq1})\right] \\ m_{M2}=\dfrac{3}{2} z_p \left[\psi_p i_{sq2}+i_{sd2} i_{sq2}(L_{sd2}-L_{sq2})\right] \\ m_\Sigma=m_{M1}+m_{M2}=m_m+\dfrac{J}{z_p}\dfrac{d\omega}{dt} \\ F_\Sigma=k_1(i_{2d}-i_{1d})+k_1(i_{2d}-i_{1d})z-k_2 z \end{cases} \qquad (1)$$

Where:

$$k_1=2\frac{\mu_0^2 N^2}{g_0^2}\psi_p;\ \ k_2=2\frac{\mu_0}{S_p g_0}\psi_p^2.$$

The stucture of AFPM motor as methematical model (1) is presented in Figure 2.

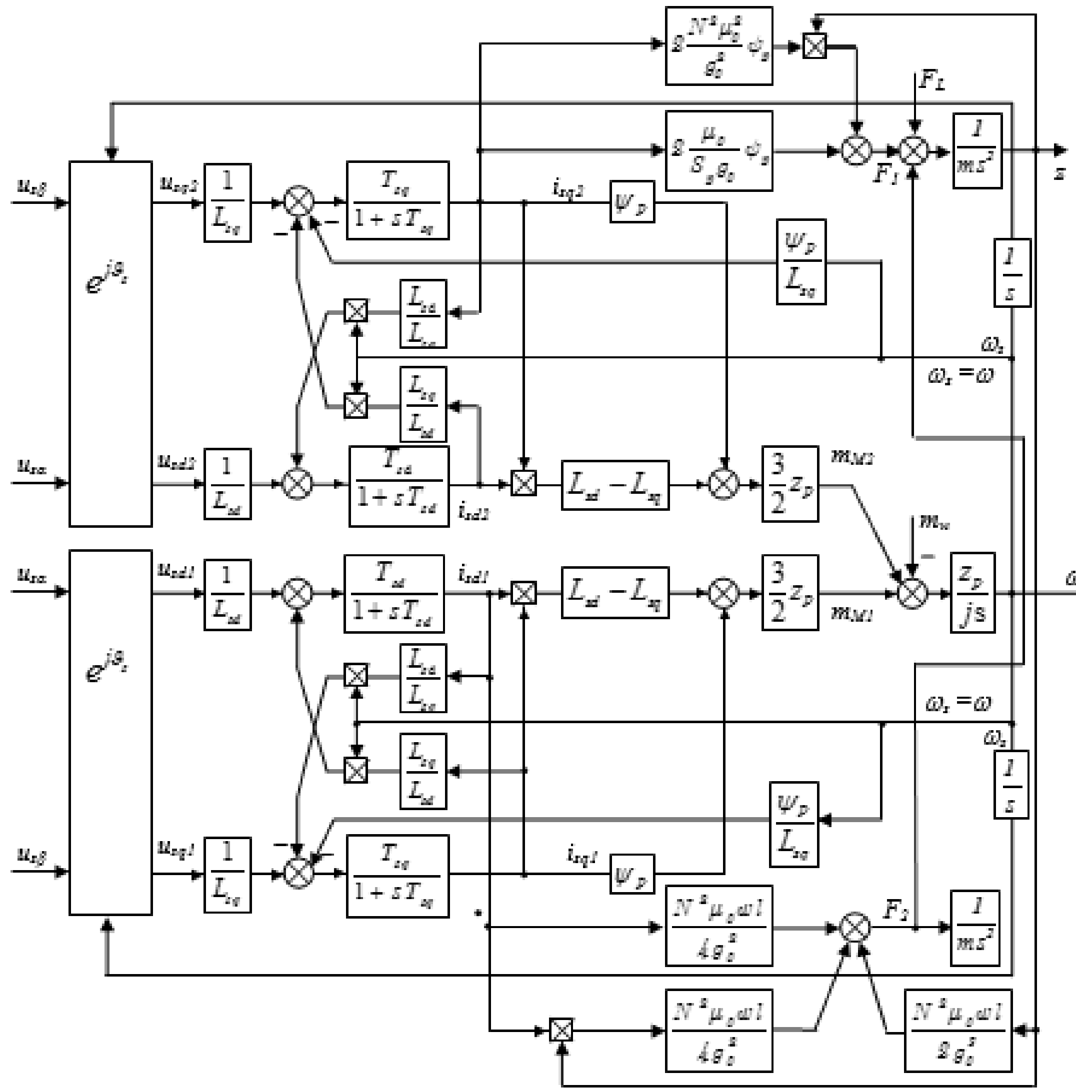

***Figure 2**: Structure diagram of AFPM motor*

III. CONCLUSION

The AFPM motor with special structure is used in combination with magnetic bearings to form a system which includes two control loops: the speed control loop and the rotor displacement control loop (with assumtion that the magnetic bearings fullfil their nominal functions).

With the results obtained, further development will be carried out as follows

- Speed control above the nominal speed is attained by flux weakening thank to apply a current isd opposite in direction with the flux ψp while sustaining the torque.
- The rotor is always kept at the center of the motor by the rotor axial displacement control loop.

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