Study, application and comparison of control techniques for a bearingless machine

Rafael Augusto de Oliveira Guedes*, Andrés Ortiz Salazar**, Rodrigo de Andrade Teixeira***, André Laurino Maitelli**** and Werbet Luiz da Silva*****

*Programa de Pós-Graduação em Engenharia Elétrica e Computação (PPgEEC), Universidade Federal do Rio Grande do Norte (UFRN), Brasil.

**Departamento de Computação e Automação (DCA), Universidade Federal do Rio Grande do Norte (UFRN), Brasil.

***Programa de Pós-Graduação em Engenharia Elétrica e Computação (PPgEEC), Universidade Federal do Rio Grande do Norte (UFRN), Brasil.

****Departamento de Computação e Automação (DCA), Universidade Federal do Rio Grande do Norte (UFRN), Brasil.

*****Universidade da Integração Internacional da Lusofonia Afro-Brasileira (Unilab), Brasil.

1. Introduction

Magnetic levitation is a phenomenon that allows objects to be suspended in the air using forces capable of counterbalancing gravity. This technology has applications in areas such as urban transport [1], wind turbines and bearingless machines [2], standing out as a relevant field for innovations and advanced studies. This article aims to present the study, application and comparison between two types of control for magnetic levitation in a permanent magnet motor for rotor position control in one degree of freedom (DoF): the control with active rejection of disturbances (ADRC) and a Proportional-Integral-Derivative (PID) control.

2. System structure

The proposed control system is applied to a bearingless permanent magnet motor, so that the rotor shaft remains close to the bottom of the stator. The position of the rotor is collected by capacitive sensors, which capture precise data about its displacement. These signals are sent to conditioning boards, which are responsible for adjusting the voltage values within a range compatible with the voltage values supported by the input of the analog/digital converter used.

For system control, the Digital Signal Processor (DSP), model TMS320F28379D from Texas Instruments, is used, which receives the voltage signals from the sensors and executes the radial position control algorithm. After processing, the control signals are modulated through PWM (Pulse Width Modulation) channels and sent to a conditioning board (driver) responsible for the amplification and activation of static switches (IGBT's) of a three-phase converter. In turn, the converter currents control the movement of the rotor until the reference position is reached. Figure 1 shows in an organized way how the complete system connection occurs.

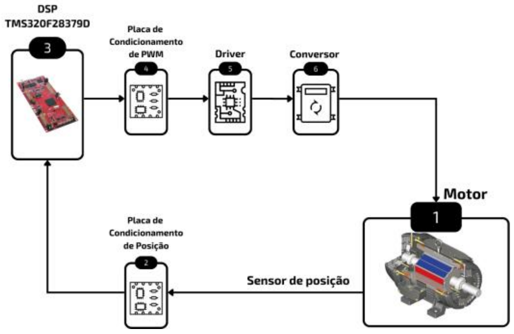

Figure 1 – System block diagram. Source: Author’s own work, 2025.

3. Controls Applied

The following are the structures of the two types of controllers used for tests on the bearingless permanent magnet motor.

3.1. Proportional-Integral-Derivative

The PID controller is widespread in research in the control area, as well as used in various industrial processes. It is composed of three different actions, the proportional, responsible for taking the output of the plant to the reference in the shortest possible time, the integrative, which aims to nullify the error in the system's steady regime, and the derivative action, which tries to keep the error at a minimum possible value. The combination of these three actions forms a PID control, which is characterized by the precise handling of a process, removing oscillations and increasing efficiency. Figure 2 shows the simplified block diagram of a PID-controlled object.

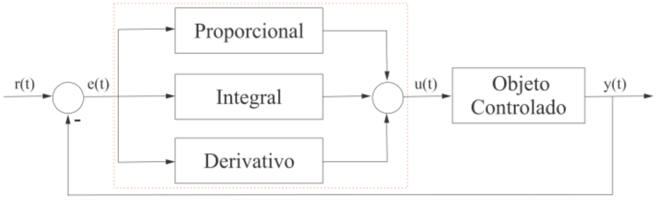

Figure 2 – PID Control Block Diagram. Source: Author's own work, 2025.

3.2. ADRC

Like the PID, the ADRC was proposed for control in one degree of freedom. The general control structure is composed of three structures: a tracking *differentiator* (TD), which generates a smoothed version of the input signal and its derivatives; an extended *state observer* (ESO), which estimates plant states and generalized disturbance; and a law of control that emulates a simpler system [3].

Figure 3 shows, through a block diagram, a general idea of the ADRC controller's operating principle. The extended state observer (ESO) uses data from the plant output and the control signal to estimate the system states and the generalized disturbance. This variable, in turn, can contain a wide variety of uncertainties and effects such as external disturbances, unmodeled internal dynamics, variations in internal parameters, and nonlinearities. The area highlighted in red represents the actual dynamics of the plant and the extended state observer in the control system with ADRC.

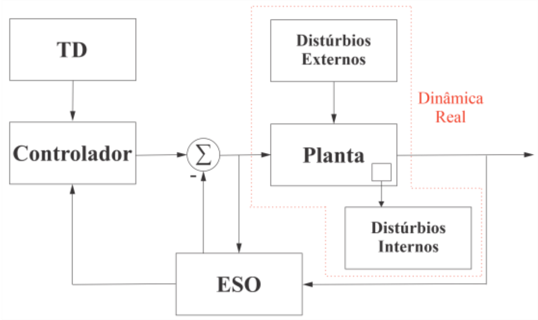

Figure 3 – ADRC Control Block Diagram. Source: Author's own work, 2023.

4. Results

Figure 4 shows the result of ADRC control in one DoF, other results will be discussed in the final version.

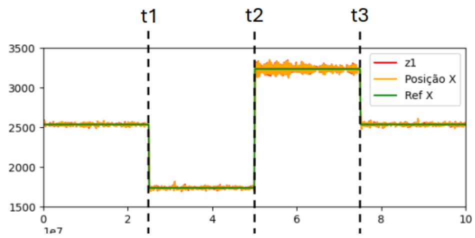

Figure 4 – X-axis position ADRC control. Source: Author's own work, 2025.

References

[1] M. Cavagnaro and V. Delle Site, "A new concept of modular magnetic levitation train for urban transport", *Transportation Systems and Technology*, vol. 4, no. 2, pp. 107-119, 2018.

[2] TEIXEIRA, Rodrigo et al. Practical results of ADRC applied to Radial Position Control of a Bearingless Induction Machine. ISMB18. 2023.

[3] TEIXEIRA, Rodrigo de Andrade et al. Application of active disturbance rejection in a bearingless machine with split-winding. **Energies**, v. 16, n. 7, p. 3100, 2023.