Design, Implementation and Testing of an Educational Test Bench for the Control of Asynchronous Motors with Encoder

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***Abstract*—This thesis presents a complete system for controlling an asynchronous motor. The system includes an induction motor mechanically coupled to a DC motor that serves as a load, a three-phase inverter, a Nucleo board, and a magnetic encoder mounted on a custom-designed support. The encoder support was modeled using CAD software, 3D printed, and incorporated into the system to provide rotor position feedback. Once the motor was equipped with the encoder, a real-time correction algorithm was implemented to compensate for inaccuracies in the encoder data, from which the rotor position and speed are derived. This correction addresses issues related to the encoder setup, such as mechanical imperfections and assembly tolerances, ensuring precise rotor position measurement and improved motor control performance. Several control strategies were implemented and tested. Initially, basic open-loop methods such as V/Hz and I-Hz were employed to calibrate the magnetic encoder, verify basic functionality and tune the current loops. After these preliminary tests, more advanced control techniques such as Field-Oriented Control (FOC) were implemented using the mounted encoder, clearly demonstrating the performance improvement achieved by equipping the motor with the encoder.**

I. Introduction

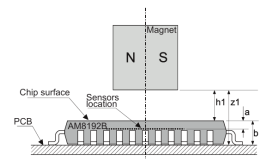
The objective of this thesis is to upgrade the educational test bench setups in the Tommasini Laboratory at the Politecnico di Torino by developing a support system capable of equipping each asynchronous motor with an encoder. The support design accounts for differences among the experimental setups and is engineered for easy assembly and disassembly. This upgrade enables the implementation of advanced control techniques rather than relying solely on simple open-loop methods and facilitates the analysis of different dynamic responses.

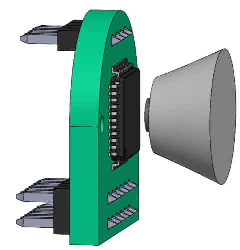
II. Hardware Overview and Assembly

The motor control system consists of:

- The NUCLEO-F303RE board based on the STM32 F303RE microcontroller in LQFP64 package.
- The X-NUCLEO-IHM08M1 inverter expansion board based on STripFET™ F7 Power MOSFET STL220N6F7, designed to operate with STM32 Nucleo boards.
- A diametrically polarized SmCo17 magnet and the RMK3B evaluation board, which includes the AM8192B angular magnetic encoder IC along with the necessary components mounted on a PCB.

The AM8192B uses Hall sensor technology to detect the magnetic flux density distribution generated by a magnet placed above the chip. The Hall sensors are arranged in a circular array on the silicon surface and are sensitive only to the perpendicular component of the magnetic flux density. Therefore, the magnet must be precisely centered on the encoder chip and positioned at the optimal distance, as specified in the datasheet. Any deviation in distance or misalignment can result in inaccuracies in the encoder readings, leading to incorrect angular position sensing. The encoder support was designed by first modeling the motor shaft support structure in SolidWorks.





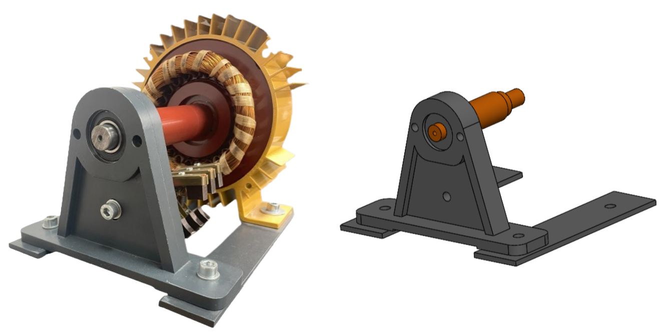
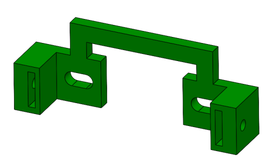
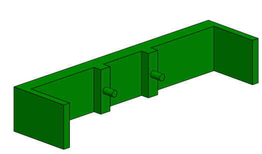


Fig. 1. Motor Shaft Support Structure: Physical and CAD Model.

Furthermore, the rotor of the induction motor is typically interchanged between the squirrel cage type and the wound type. To address these requirements, the encoder support was designed as a two-part structure. One component is intended to be fixed to the motor shaft support with screws, while the other houses the evaluation board.





This movable part slides within the fixed part to achieve the proper distance and alignment between the magnet affixed to the shaft and the sensor. Fig. 2 shows the encoder support integrated into the system and the complete test bench setup.

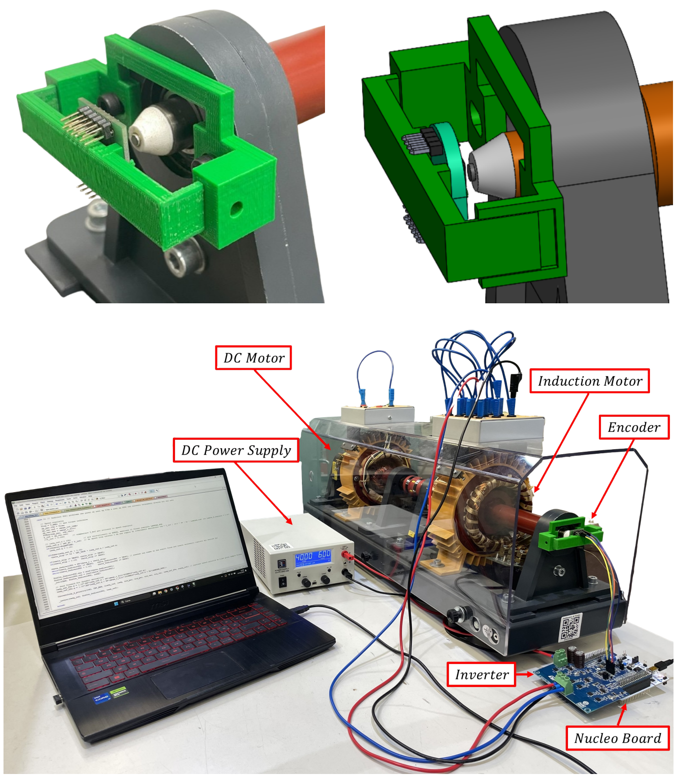


Fig. 2. Encoder Support and Experimental Setup.

III. Real-Time Correction

Along with the encoder signals, the evaluation board outputs a misalignment signal to help align the sensor with the magnet. However, the limited precision of the 3D printed components complicates achieving perfect alignment and optimal spacing between the two. Therefore, a real-time correction algorithm was implemented to adjust the rotor position measurement derived from the encoder readings, preventing inaccuracies.

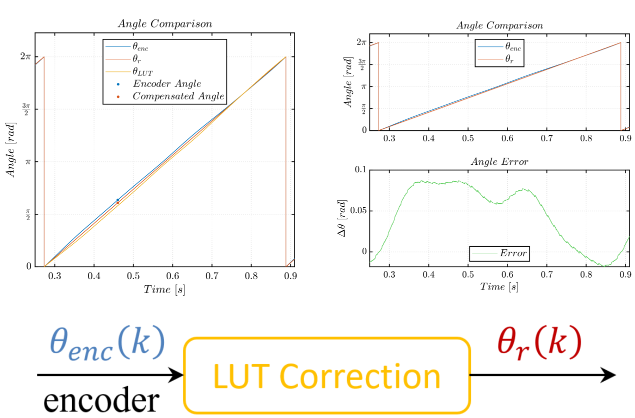
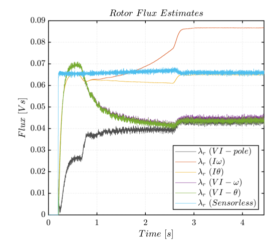


Fig. 3. Rotor Position Correction.

To compensate for encoder inaccuracies, a look-up table (LUT) is generated at every motor startup. During this phase, the motor performs a few turns to collect encoder data, which naturally include distortions due to misalignment. The acquired values are compared with the ideal theoretical values, which follow a perfect sawtooth pattern, and the LUT is generated by interpolation between these data sets. Although the resulting LUT is non-linear, it is inversely related to the encoder error. When applied in real time, this correction provides output data that accurately represent the actual rotor position.

IV. Experimental Results



The implemented FOC techniques employ closed-loop speed control using the encoder, ensuring more precise tracking of the speed reference compared to open-loop V/Hz and I-Hz controls. Real-time correction of the rotor position is crucial for accurate speed calculation, as directly relying on the raw encoder data would introduce errors. Additionally, this correction is essential in Direct FOC, as this control technique is based on flux estimators or observers that require precise rotor position or speed measurements. Fig. 4 illustrates an example of the improved dynamic performance achieved with Direct FOC compared to open-loop controls.

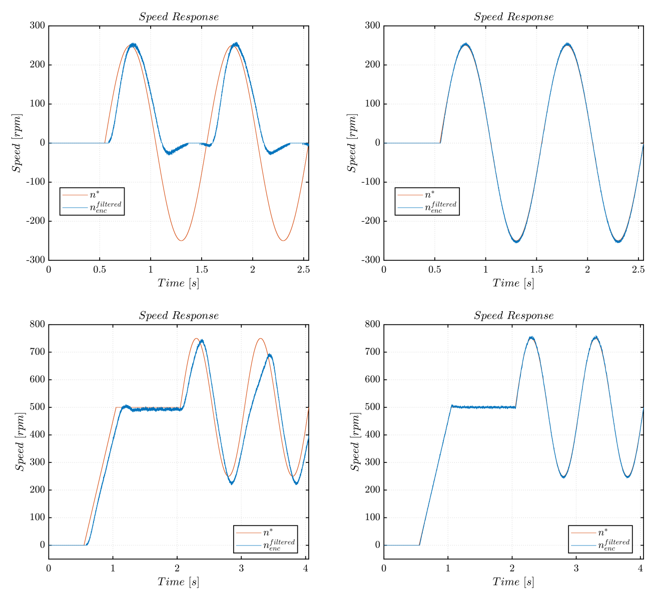


Fig. 4. Speed Response Tests: V/Hz and I-Hz (Left) vs. DFOC (Right).

V. Conclusions

Both the designed encoder support and the implemented real-time correction of the encoder readings have proven effective. Their combination adapts to slight variations among the experimental test benches intended to be equipped with this type of sensor and addresses issues arising from the limited precision of the 3D printed components. Moreover, controlling the motor using the encoder feedback results in better dynamic performance compared to simpler control methods.