

# Hybrid Control Approach Using G-IoT for Active Magnetic Bearings

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## 1. Introduction

Active Magnetic Bearings (AMBs) have been crucial in many industrial applications, such as the oil and gas industry, energy industry, and environmental protection, as well as in research studies [1]. However, due to their inherent instability and nonlinear behavior, advanced control systems such as intelligent control systems, Artificial Neural Networks (ANN), Fuzzy Logic Controllers (FLC), Proportional Integral Derivative (PID) were applied on AMB systems [2]. Although their advancements have made it possible for their application to become more widespread beyond laboratory environments, actively controlled magnetic bearings aren't yet a prevalent option in the market [2]. Wu and Zhang [3] further outlined that while PID control holds a dominant position in current systems, it can be insufficient on its own and often needs to be combined with other control strategies to achieve better performance. Given, new, more innovating and more advanced control methods are foremost for future research on AMBs [3]. Some recent and innovative applications on AMBs are the use of Internet of Things (IoT) for remote condition monitoring [4], benefiting lowered costs, and fault detection using digital twin technology [5]. Such strategies are applicable for markets due to the remote, cheap, and accurate methods they offer and highlight the potential for digital solutions on AMB system performance development. Also taking into account that AI based control approaches along with the classical controllers can increase the reliability and performance of the overall AMB system [6] and that LLMs outperform specialized AI models in multi-objective, highly variable applications [7] with greater transparency, this paper offers a hybrid control approach via integrating a Generative AI Based Internet of Things (G-IoT) technology for slower and higher-level control and parameter optimization to a local controller.

## 2. G-IoT Technology

G-IoT is the integration of Generative Artificial Intelligence (GenAI) into modern IoT [8]. Given the capabilities of GenAI in advanced decision-making processes such as forecasting future events or predicting system failures by processing historical sensing data and real-time sensor readings [8], G-IoT technology, via an integration of a GenAI based controller-agent into the AMB system through an IoT gateway, has the potential to increase accuracy, efficiency, robustness, and traceability in AMB control processes.

## 3. Agent Controller Construction

A GPT Assistant API is created as the GenAI based agent controller and informed thoroughly on the mathematical model of the AMB system with descriptions on the control system model, mechanical and electromagnetic dynamics of the system, current gains, etc. in the system instructions part. It is trained on historical AMB motion sensor data using the code interpreter tool and on the concept of active magnetic bearing theory and its working principles with its file search tool, using relevant books and journal articles, textbooks, and ISMB proceedings as main sources. The reference parameters on the specific bearing are explained to the agent so that it detects misalignments. Then, the following functions are assigned to the agent: 1) analyzing and processing the real-time data signals packaged and standardized by the edge device received from the IoT gateway, 2) determining the necessary control commands and optimal parameter suggestions comparing the input with the reference values, 3) sending the control commands as feedback signals to the controller -see Fig. 1, 4) explaining the reasoning of decisions and the possible damages/failures the AMB system might be undertaking upon request from users, 5) detachment from the system through "deactivate" command from users. After these functions integrated, the agent will be able to fully operate as an intelligent, digital, high-level controller for the AMB.

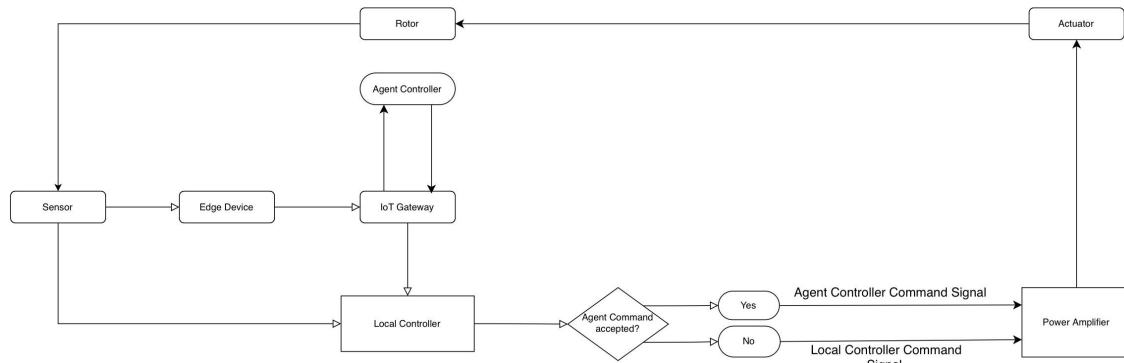


Fig. 1 Simplified block diagram showcasing the proposed hybrid controller system architecture

#### 4. Proposed System Architecture and Limitations

The general overview and workflow of the system can be seen in Fig. 1. Since the IoT gateway [4] and the agent controller are limitations for typical sampling times of AMBs, the proposed architecture would be most successful for relatively slow rotors [4] as for now. A priority-based control blend is applied, where the local controller has the priority for rapid stabilization and emergencies (such as connection breakouts). That said, agent's output is introduced as a bias on the reference values, e.g., rotor position, with a small weight that increases only when the system is within the safety threshold that is introduced to the system. Moreover, even though the agent controller is carefully constructed, fine-tuned, and weighted, it can be wrong and destabilizing at times since currently there are, to our knowledge, no study that tried out such system or a GenAI based agent on AMBs that validates its performance. Hence, an override mechanism where a safety monitor implemented in the software of the local controller that checks the responses of the agent, which is the unverified advanced controller, as the trusted baseline controller, similar to the Simplex architecture [9] is implemented.

#### 5. Conclusion and Future Outlooks

In conclusion, the agent controller periodically sends more advanced control commands and the local controller whether applies them or not according to its safety decision, while it operates full-time like a regular controller. This study is still on progress. The proposed model structure is ready as discussed throughout the digest. However, the proposed system isn't physically tested to come up with a completed (i.e., fully specified components such as a micro-controller for edge device or an on-premise MQTT for IoT Gateway), optimal (e.g., optimal local controller for the GenAI based agent controller-local controller combination) and robust version in the upcoming months through testing and evaluating. The main idea of using a hybrid controlling structure with G-IoT technology remains the same as the foundation of the publication.

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