LOW-COST AUTOMATED STORAGE AND RETRIEVAL SYSTEM

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ABSTRACT

This work focuses on designing a cost-effective Automated Storage and Retrieval System (AS/RS) tailored for small and medium-sized enterprises. A preliminary market study was conducted to identify industrial needs and limitations of existing high-cost systems. The proposed system uses three AC motors to enable movement along the X, Y, and Z axes, controlled via a Programmable Logic Controller (PLC). Positioning accuracy is achieved using inverters and incremental encoders. A flexible Human Machine Interface (HMI) is developed to integrate with existing Enterprise Resource Planning (ERP) systems. A prototype has been implemented and tested, demonstrating satisfactory performance in handling moderate loads efficiently.

Keywords: AS/RS; PLC motion control; inverter; incremental encoder.

I.INTRODUCTION

Modern warehouses handle large volumes of goods and require efficient systems to manage storage and retrieval operations. Early automation efforts mainly aimed to reduce manual labor and travel distance. However, today's focus has shifted toward improving operational speed, accuracy, and efficiency.

An Automated Storage and Retrieval System (AS/RS) is a computer-controlled system that automates the movement of goods within storage facilities. It includes storage racks, retrieval mechanisms, identification technologies (such as barcodes or RFID), and integration with ERP systems.

Despite their benefits, most AS/RS solutions are designed for large-scale industries and involve high investment costs. This makes them impractical for small and medium enterprises (SMEs), especially in markets with limited standardization. Therefore, there is a strong need for an affordable, adaptable, and efficient AS/RS solution suitable for smaller operations.

II.LITERATURE REVIEW

Method Previous research has explored multiple aspects of AS/RS, particularly focusing on:

Travel Time Optimization: Studies have analyzed how system efficiency depends on minimizing the movement time of storage and retrieval devices.

Storage Allocation Strategies: Research suggests placing frequently accessed items closer to input/output points to reduce retrieval time.

Operational Modes: Systems operate in single-cycle (store or retrieve) or double-cycle (store and retrieve in one trip) modes, with double-cycle offering better efficiency but requiring complex coordination.

Order Processing Methods: Static batching and dynamic scheduling methods have been studied, with dynamic approaches showing better performance in real-time environments.

Queuing Models and Algorithms: Advanced mathematical models (e.g., M/G/1 queues) and algorithms have been used to evaluate and optimize system performance.

III.METHODOLOGY

The development of the proposed Automated Storage and Retrieval System (AS/RS) was carried out through a systematic multi-stage process to ensure both practicality and cost efficiency for small and medium-sized enterprises.

1. Requirement Analysis

The initial phase involved conducting a detailed survey among small and medium-scale industries to identify their operational needs and limitations. The study focused on existing storage practices such as the use of pallets and boxes, reliance on manual or semi-automated tools like forklifts, and the extent of ERP system adoption. Additionally, parameters such as daily inventory flow, order frequency, delivery timelines, and warehouse constraints were analyzed. This phase helped define key system requirements such as flexibility, affordability, and compatibility with existing infrastructure.

2. System Design

Based on the findings, a modular system architecture was designed. The warehouse layout was structured into a grid-based shelving system to facilitate coordinate-based positioning (X-Y axes). The design included a storage/retrieval (S/R) mechanism capable of navigating through aisles, a PLC-based control system for automation, and an interface layer to integrate seamlessly with existing ERP software. Special attention was given to minimizing structural changes in existing warehouses while ensuring scalability and adaptability.

3. Motion Control

The movement of the S/R mechanism was implemented across three axes—X (horizontal), Y (vertical), and Z (depth). For X and Y movements, cost-effective three-phase AC motors were selected, coupled with inverters to control speed and incremental encoders to provide precise positional feedback. This combination enabled accurate control of acceleration, deceleration, and stopping positions. The Z-axis operation, responsible for inserting and retrieving items

from shelves, was comparatively simpler and directly managed by the PLC. The overall motion system was optimized to balance performance with cost constraints.

4. Control System

A Programmable Logic Controller (PLC) served as the central control unit, executing logic for coordinated motor movements based on input data such as target position and load parameters. The PLC continuously processed feedback from encoders to ensure accurate positioning. For enhanced precision and reliability, additional sensing mechanisms such as RFID tags or reflectors could be incorporated to verify final positions. The control logic also included safety interlocks, motion sequencing, and synchronization between different axes.

5. Human Machine Interface (HMI)

A user-friendly Human Machine Interface was developed to facilitate interaction between the operator, the AS/RS, and the ERP system. The HMI supports two primary modes: AUTO and MANUAL. In AUTO mode, operations such as item identification (via barcode/RFID), storage allocation, and retrieval are executed automatically based on ERP data and predefined algorithms. In MANUAL mode, operators can directly control system movements, adjust parameters like speed and position, and override automatic operations when necessary. The interface also includes real-time monitoring, parameter configuration screens, and essential safety features such as emergency stop controls.

6. Prototype Implementation and Testing

To validate the proposed design, a functional prototype was developed. The system was designed to handle loads within specified size and weight limits, reflecting real-world use cases. Extensive testing was conducted to evaluate motion accuracy, positioning reliability, and system responsiveness. Performance was analyzed under varying conditions, including changes in load weight, speed profiles, repeated motion cycles, and continuous operation scenarios. These tests helped assess the durability, efficiency, and operational feasibility of the system while identifying areas for further optimization.

IV.ADVANTAGES

The proposed AS/RS offers several benefits:

- **Low Cost:** Uses economical components like AC motors instead of expensive servo systems.
- **Flexibility:** Easily adaptable to different warehouse sizes and layouts.
- **ERP Integration:** Works with existing software systems, reducing implementation effort.
- **Improved Efficiency:** Reduces manual labor and speeds up storage/retrieval operations.
- **Energy Savings:** Optimized movement reduces power consumption.
- **Enhanced Safety:** Minimizes human involvement in material handling.
- **Scalability:** Can be expanded or modified based on business growth.

V.CONCLUSION

This study presents a practical and affordable AS/RS solution designed specifically for small and medium-sized enterprises. By combining cost-effective hardware with flexible software integration, the system addresses key challenges faced by smaller warehouses. The prototype testing indicates reliable performance and potential for real-world application. Future improvements can focus on optimizing algorithms, enhancing automation levels, and increasing system scalability.

VI.REFERENCES

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