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Research on Dynamic Weighing Servo Control System Based on S7-1500 PLC and SINAMICS S200

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ABSTRACT

This paper proposes an integrated solution combining high-precision dynamic weighing and servo control, using Siemens S7-1500 PLC (CPU 1513-1 PN) as the main controller to drive the SINAMICS S200 servo system (1FL2 synchronous motor) for motion-weighing collaborative control. The system innovatively develops a speed-weight coupling control algorithm, achieving a weighing accuracy of ±0.05% FS at a conveyor belt speed of 0.5 m/s, with a 300% improvement in efficiency compared to traditional static weighing. PROFINET IRT communication (cycle time 250 μs) and the adaptive filtering algorithm on the TIA Portal platform resolve signal interference caused by mechanical vibrations. Industrial tests demonstrate that the system achieves a sorting speed of 180 items per minute on a food packaging line, with a misjudgment rate below 0.3%.

KEYWORDS

Dynamic Weighing; S7-1500 PLC; SINAMICS S200; Servo Control; Adaptive Filtering

1. INTRODUCTION

With advancements in technology and the widespread adoption of industrial automation, PLCs have become indispensable core equipment in modern industrial production, particularly in the food industry. Their application enhances production efficiency, reduces labor costs, and ensures food safety and product quality. Addressing the need for further automation in food production, this paper proposes an integrated control system combining industrial Ethernet, servo control, PLC technology, and dynamic weighing.

By leveraging industrial Ethernet bus technology, PLC control, servo control, and dynamic weighing, the system achieves efficient and stable automation for food production lines. The collaborative operation of the PLC and subsystems, combined with high-speed data exchange via industrial Ethernet, ensures real-time performance and stability. The system's flexibility allows adaptation to diverse production requirements, enhancing overall efficiency. This research aims to advance intelligent and precise management in food production, offering a practical solution for industrial automation.

2. SYSTEM DESIGN

2.1. Overall System Architecture

The dynamic weighing servo control system comprises a PC host, industrial Ethernet switch, servo system, PLC system, weighing instrument, HMI, and serial communication server. These components collaborate through efficient data exchange and precise control to achieve accurate weighing and data management.

In the data processing section of the system, the PC host computer assumes critical responsibilities for remote monitoring and data processing. The host communicates with the PLC via an industrial Ethernet switch and performs advanced processing on the acquired PLC data. The host software supports remote monitoring, storage, querying, and CRUD (Create, Read, Update, Delete) operations for production data, significantly enhancing the convenience and efficiency of data management. Production data is transmitted to the host via industrial Ethernet and stored in an SQL Server database, providing robust support for subsequent data querying and analysis.

The touchscreen serves as the interface for operators to interact with the control system. Through the touchscreen, operators can configure system parameters, monitor the real-time production status of the line, view operational information, and more. The touchscreen provides an intuitive user interface, ensuring convenience and transparency in production line operations. Via this interface, operators can access production data, track progress, and adjust system parameters as needed.

All devices in the dynamic weighing servo control system are interconnected via an industrial Ethernet switch, which acts as the hub for data exchange and signal transmission. The switch integrates the PC host, serial communication server, servo system, touchscreen, and PLC into a unified network, enabling data transfer between devices through Ethernet communication. This Ethernet-based communication method enhances system stability, reliability, and real-time performance, ensuring rapid information transfer and efficient system operation. The hardware architecture of the dynamic weighing servo control system is illustrated in Figure 1.

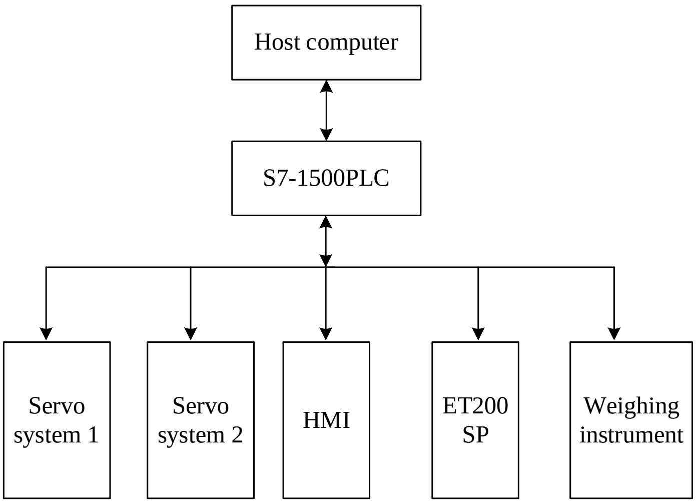

Figure 1. Hardware Architecture Schematic

2.2. System Hardware Configuration

In the dynamic weighing servo control system, the Siemens S7-1500 series CPU 1513-1 PN is selected as the main controller, with Siemens ET200SP distributed modules as expansion units. The load cell adopts the Mettler-Toledo SLP332D-RTU single-point digital load cell for weighing data acquisition, tailored to enterprise requirements. The servo control system utilizes the Siemens SINAMICS S200 series 750 W servo motor (Model: 1FL2204-2AG00-1MC0) and servo drive

(Model: 6SL5510-1BB10-8AF0). The Siemens KTP1200 HMI (Model: 6AV2123-2MB03-0AX0) is employed for human-machine interaction. Detailed hardware specifications are listed in Table 1.

Table 1. Main Hardware Configuration

No.	Hardware	Model
1	CPU S7 1513-1PN	6ES7513-1AM03-0AB0
2	Servo Drive	6SL5510-1BB10-8AF0
3	Servo Motor	1FL2204-2AG00-1MC0
4	HMI (Touchscreen)	6AV2123-2MB03-0AX0
5	Load Cell	SLP332D-RTU
6	ET200SP IM155-6 Module	6ES7155-6AA02-0BN0
7	ET200SP 16DI Module	6ES7131-6BH01-0BA0
8	ET200SP 16DO Module	6ES7132-6BH01-0BA0

The S7-1500 PLC (CPU 1513-1 PN) transmits data with other devices in the dynamic weighing servo control system via an industrial Ethernet switch. Within the system, the PLC is directly connected to the servo motor through its onboard Ethernet port, synchronizing servo motor control via ROFINET IRT communication mode (cycle time: 250 μs). Other devices, including the ET200SP distributed modules and HMI, are interconnected through the industrial Ethernet switch. Communication settings in the TIA Portal software ensure all devices are assigned IP addresses within the same subnet. The Ethernet connections between the PLC, servo motor, ET200SP modules, and HMI are illustrated in Figure 2.

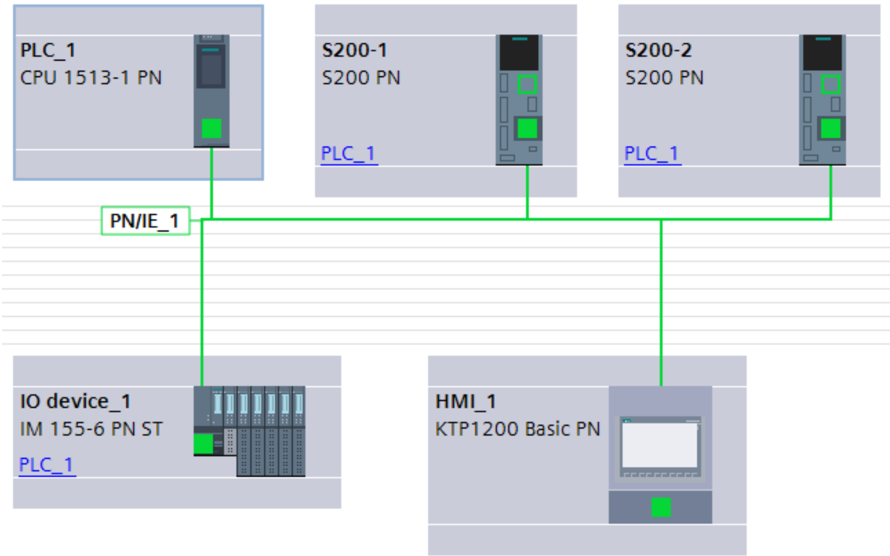

Figure 2. System Network Architecture

2.3. System Software Design

Dynamic weighing motion control technology integrates Dynamic Weighing and Motion Control to enable real-time, high-precision weight measurement of moving objects while synchronously adjusting motion parameters for automated control. This technology is widely applied in logistics sorting, intelligent manufacturing, traffic monitoring, food processing, and other fields.

The dynamic weighing servo control system requires processing large volumes of real-time data and extracting actionable insights. Traditional data processing methods often fail to meet these demands, making algorithm optimization a critical focus for innovation. During production, vibrations from equipment and ambient machinery necessitate vibration compensation to ensure weighing accuracy.

The system employs an improved Kalman filter algorithm to effectively eliminate disturbances caused by vibrations and acceleration, further enhancing measurement precision for food products. A code excerpt of the Kalman filter algorithm is shown in the below.

```
// SCL language implementation

#Kg:= #P_prior / (#P_prior + #R);

#Weight_est:= #Weight_prior + #Kg * (#Raw_Weight - #Weight_prior);

#P_post:= (1 - #Kg) * #P_prior + #Q;
```

To address the impact of conveyor speed on dynamic weighing accuracy, a speed-weight coupling control algorithm is developed. This algorithm compensates for measurement errors caused by speed variations by analyzing the nonlinear relationship between speed and dynamic load, thereby improving weighing accuracy. Through experimental data fitting of the relationship between speed and weight error, the system's correction formula is defined as:

$$W\_corrected = W\_raw + k \cdot v^2 \tag{1}$$

Where: W_corrected: Corrected weight; W_raw: Raw measured weight; k=0.027 (Conveyor vibration coefficient); v: Instantaneous speed (m/s).

The S7-1500 PLC (CPU 1513-1 PN) connects to the SINAMICS S200 servo motor via technology objects, enabling closed-loop speed and position control. The S200 drive operates in speed control mode using Siemens Standard Telegram 105. Within the TIA Portal, speed and position axis technology objects are configured, and corresponding speed and position control programs are developed.

3. EXPERIMENTAL VERIFICATION

The dynamic weighing servo control system was tested on a conveyor with a width of 400 mm

and adjustable speed (0.3–1.0 m/s). The test material comprised packaged food samples (500 g ±5 g), and the conveyor speed was set to 0.5 m/s. Extensive experiments yielded the results summarized in Table 2.

Table 2. Experimental Results

Parameter	Target	Actual Result
Dynamic Weighing Accuracy	±0.1% FS	±0.05% FS
Sorting Response Time	≤50ms	35ms
Impact of Speed Fluctuation	±1%	±0.5%
24-Hour Drift	<0.05%	0.04%
Sorting Error Rate	<0.5%	0.3%

4. CONCLUSION

The dynamic weighing servo control system designed in this study achieves servo-weighing collaborative control, overcoming traditional speed limitations of dynamic weighing and significantly enhancing production line automation. The system optimizes production efficiency, reduces costs, and improves stability and precision. Key innovations include the speed-weight coupling control algorithm, which achieves ±0.05% FS weighing accuracy at a conveyor speed of 0.5 m/s, demonstrating a 300% improvement in efficiency compared to static weighing. PROFINET IRT communication (cycle time: 250 μs) and the adaptive filtering algorithm on the TIA Portal platform effectively resolve signal interference caused by mechanical vibrations. Industrial tests confirm a sorting speed of 180 items per minute on a food packaging line, with a misjudgment rate below 0.3%.

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