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Design and Development of an Industrial Form-Fill-Seal (FFS) Packaging Machine

Kartik Yogesh Pachpol
Dept. of Electronics and Telecommunication
Sinhgad College of Engineering
Pune, India

Shruti Vijay Kadam
Dept. of Electronics and Telecommunication
Sinhgad College of Engineering
Pune, India

Pratiksha Nana Girme
Dept. of Electronics and Telecommunication
Sinhgad College of Engineering
Pune, India

Prof. V. B. Baru
Dept. of Electronics and Telecommunication
Sinhgad College of Engineering
Pune, India

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***Abstract*—Form-Fill-Seal (FFS) machines are widely used in packaging industries to automate the processes of forming, filling, sealing, and cutting packages. However, industrial FFS machines are costly, mechanically complex, and not suitable for classroom demonstrations or introductory training in automation systems. To address this limitation, a compact PLC-HMI based FFS demonstration platform was developed to represent the operating sequence of an industrial packaging machine in a safe and simplified manner.**

The developed system uses a B&R Power Panel C50 integrated controller and Human-Machine Interface (HMI) operating on a 24 V DC supply. Sixteen toggle switches are used to simulate machine inputs, while sixteen LED indicators represent machine outputs such as film feeding, filling, sealing, cutting, and alarm conditions. The control sequence was implemented using PLC logic and tested under different operating conditions to verify correct system behaviour.

Experimental testing confirmed reliable execution of the programmed sequence and proper response to start, stop, and emergency commands. The developed platform provides a practical way to demonstrate industrial automation concepts, PLC programming, HMI operation, and machine-sequence control without the safety risks and cost associated with a full-scale packaging machine.

***Index Terms*—Form-Fill-Seal, PLC, HMI, packaging automation, industrial control, ladder logic.**

I. INTRODUCTION

Packaging plays an important role in manufacturing industries where product quality, consistency, and production speed are important. As production requirements increase, automated packaging systems are increasingly preferred because they reduce manual intervention while maintaining repeatable operation.. Among the available packaging solutions, Form-Fill-Seal (FFS) machines are widely used because they combine pouch formation, product filling, sealing, and cutting into a single automated process.

Industrial FFS machines provide high productivity and reliable operation; however, they involve complex mechanical assemblies, heating systems, sensors, and motion-control mechanisms. The cost of such equipment, along with the associated safety considerations, makes it difficult to use full-scale machines for laboratory demonstrations, introductory training, or educational activities.

To address this challenge, this project focuses on the development of a PLC-HMI based demonstration platform that represents the operational sequence of an FFS machine in a simplified manner. Instead of using actual sealing mechanisms, motors, and process sensors, the system employs toggle switches and LED indicators to simulate machine inputs and outputs. This approach allows the control sequence to be studied, tested, and demonstrated safely while preserving the fundamental logic of industrial FFS operation.

This paper describes the design and development of such a platform: a compact FFS demonstration kit driven by an

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A. integrated PLC and HMI. The mechanical actuators and sensors of a production machine are deliberately replaced by sixteen toggle switches (representing input *Control and Automation Approaches*

PLC and HMI technologies are widely used in industrial automation because they provide reliable control, monitoring, and operator interaction. Algitta et al. developed an automated packaging system controlled through PLC-based logic and demonstrated effective sequencing of packaging operations [5].

A related study by Bhanwrela et al. presented a horizontal flow-wrap packaging machine that used a Mitsubishi FX5U PLC and HMI for process control and monitoring. Their work demonstrated how automation can improve packaging efficiency while simplifying machine operation through graphical user interfaces [6].

The application of PLC-HMI systems extends beyond packaging processes. Rahman et al. developed a PLC-HMI based paper-cutting machine in which the controller managed machine operation while the HMI allowed users to enter process parameters and monitor system status [7]. Similarly, Mofidul et al. proposed a remote monitoring solution for a PLC-based packaging system that enabled supervision of machine operation through communication technologies [8].

Studies related to sorting, material handling, and packaging automation consistently demonstrate the advantages of PLC-based control, including reliable sequencing, simplified troubleshooting, and flexible system operation. These observations influenced the design approach adopted in the present work, where PLC logic and HMI interaction are used to demonstrate the operating sequence of an FFS machine [9].

conditions such as film position, fill command and limit signals) and sixteen LED indicators (representing outputs such as film movement, filling, sealing, cutting and alarm states). This substitution preserves the logical structure of the machine cycle while keeping the entire system at a safe 24 V DC level. The platform is intended for three purposes: educational instruction in industrial automation, safe testing and validation of control logic, and portable demonstration of packaging-automation concepts.

The remainder of this paper is organised into five sections. Section II presents the literature review related to FFS systems and packaging automation. Section III describes the system design, electrical architecture, and control methodology. Section IV discusses the implementation results and system performance. Finally, Section V presents the conclusion and future scope of the work.

II. LITERATURE REVIEW

The literature relevant to this project spans two areas: the mechanical and material aspects of FFS machine design, and the control and automation approaches used in packaging systems.

B. FFS Machine Design and Sealing

A number of recent studies have focused on improving the performance of Form-Fill-Seal machines through better

film handling and sealing techniques. Merabtene et al. investigated the behaviour of paper-based packaging materials in vertical FFS systems and reported challenges such as wrinkling, web buckling, and variations in seal quality. Their work highlighted the importance of proper material handling and sealing conditions in maintaining packaging quality [2].

In a subsequent study, Merabtene et al. proposed an improved forming-shoulder design for coated paper-based materials used in vertical packaging systems. The modified design helped reduce wrinkles and material deformation during operation, demonstrating the influence of mechanical design on overall machine performance [3].

Research has also been carried out to improve packaging speed and sealing efficiency. Sachin M. and Sree Rajendra developed a continuous-motion VFFS sealing mechanism aimed at increasing machine productivity while maintaining reliable sealing performance. Their work showed that design improvements in the sealing section can contribute significantly to overall machine efficiency [4].

These studies indicate that machine performance depends not only on the control system but also on proper coordination between film handling, sealing mechanisms, and machine design.

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C. Summary

The reviewed literature shows that successful packaging systems depend on the combined performance of machine design, sealing mechanisms, material handling, and automation control. Previous studies have largely focused on improving production performance, packaging quality, and machine efficiency in industrial environments. However, limited attention has been given to the development of compact educational platforms that demonstrate packaging-machine control logic in a safe and simplified manner.

The present work addresses this gap by developing a PLC-HMI based FFS demonstration platform that focuses on understanding machine sequencing, operator interaction, and industrial control concepts without requiring a full-scale packaging system.

III. SYSTEM DESIGN AND METHODOLOGY

The system integrates electrical and automation components to reproduce the form, fill and seal sequence while operating safely at low voltage. Development proceeded in three phases: a design phase (conceptual and electrical design, block diagrams and control flow); an implementation phase (construction of the control panel and wiring, with layouts prepared in AutoCAD); and a testing and validation phase (uploading the control program, simulating machine cycles and verifying the correct sequence of operations).

A. System Architecture

The platform is organized into three functional layers: a power and safety layer, a control-logic layer and an output-execution layer. Fig. 1 shows the functional block diagram. Mains 230 V AC enters through an MCB and emergency-stop circuit, is converted to 24 V DC by a switched-mode power supply (SMPS), and feeds the integrated controller and the input/output devices. Operator and simulated-sensor inputs enter the controller, which drives the LED outputs according to the programmed logic.

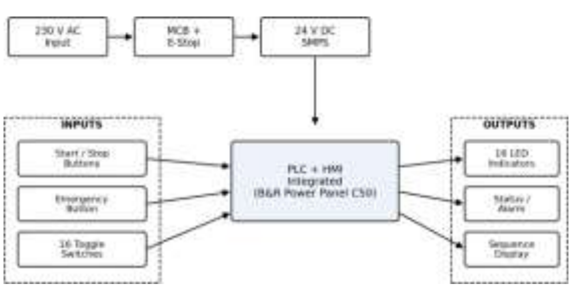

Fig. 1. Functional block diagram of the FFS demonstration platform.

B. Electrical System Design

The electrical design ensures safe power distribution and precise control of the simulated machine operations.

1) Power and Safety Section: The power section accepts a 230 V AC input and protects the system through an MCB (over-current and short-circuit protection) and an emergency-stop control that cuts power instantly. A 24 V DC SMPS converts the mains supply to a regulated low voltage that powers the controller and all logic and indication devices. Operating the entire control and indication system at 24 V DC is a deliberate safety decision that makes the platform suitable for unsupervised classroom use.

2) Control and Logic Section: The core of the platform is a B&R Power Panel C50 (order number 4PPC50.0702-10B), a device that integrates a controller and a 7.0″ touch HMI in a single unit. The controller provides POWERLINK, Ethernet, X2X Link and USB interfaces and operates from a 24 V DC supply, with a maximum power consumption of approximately 21 W [12]. The integrated HMI displays system status, allows parameters such as fill time and cycle delay to be changed, and supports manual operation, while the controller executes the ladder-logic program developed in B&R Automation Studio [13].

Inputs to the platform are provided by sixteen toggle switches, which stand in for the sensors and control signals of a real FFS machine (for example film position, filling command and limit signals). Outputs are represented by sixteen LED indicators, each mapped to a specific machine operation such as film movement, filling, sealing, cutting or alarm indication. The wiring of these inputs and outputs to the controller's digital channels is labelled systematically (DI-1 to DI-16, DO-1 to DO-16) to mirror professional panel-building practice.

3) Panel Load: Table I summarises the estimated electrical load of the panel. The SMPS dominates the load, while the controller, indicators and switches draw modest currents consistent with low-voltage logic-level operation.

TABLE I. Panel Load Estimate

Component	Voltage	Current	Power
PLC + HMI	24 V DC	0.2–0.3 A	4.8–7.2 W
SMPS (input)	230 V AC	0.6 A	120 W
Temp. controller	24 V DC	0.1 A	2.4 W
LED indicators	24 V DC	0.02 A each	~8 W
Toggle switches	24 V DC	~0.6 A	~14.1 W

C. Control Logic and Algorithm

The control logic is implemented as a PLC program in which the sixteen toggle switches act as inputs and the sixteen LEDs act as outputs. The operational sequence is as follows:

1) **Idle state.** The system remains idle until a start command is given through the HMI or the start button. All LED outputs are off.
2) **Input activation.** The operator sets toggle switches that simulate the various sensor and input conditions of the machine.

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3) **Processing.** The controller reads the state of all sixteen switches and processes them according to the programmed sequence.
4) **Output indication.** Based on the inputs, the controller drives the corresponding LEDs, each representing a machine operation such as film movement, filling, sealing or cutting.
5) **Sealing simulation.** In place of live heaters or motors, LED indicators visualise operations such as sealing and cutting, showing the machine cycle clearly and safely.
6) **Stop and emergency handling.** Pressing stop halts the system and turns all outputs off; pressing the emergency button immediately shuts down all outputs.
7) **Cycle repetition.** The controller continuously scans inputs and updates outputs, reproducing the continuous operation of an FFS machine.

The corresponding control flow is shown in Fig. 2.

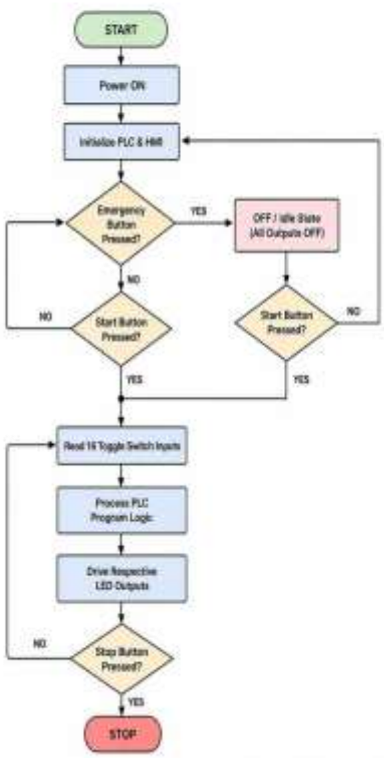

Fig. 2. Operational flow chart of the control program.

D. Hardware Realisation

The complete system is assembled in a rugged, portable enclosure. Fig. 3 shows the operator-facing panel, with the integrated HMI above and the toggle-switch and LED arrays below. Fig. 4 shows the internal power and control section, including the MCB, the 24 V DC SMPS, terminal blocks and the integrated controller mounted on DIN rail within wire ducts. Fig. 5 shows the controller's interface side and the labelled input/output wiring harness.

During assembly of the demonstration platform, particular attention was given to proper wiring, terminal identification, and I/O mapping between the controller and field devices. Several rounds of testing were carried out to verify the operation of the input switches, output indicators, and HMI functions. Minor wiring and logic corrections were identified during initial testing and were resolved before final validation of the system.

Fig. 3. Operator panel: integrated HMI with toggle-switch inputs and LED indicators.

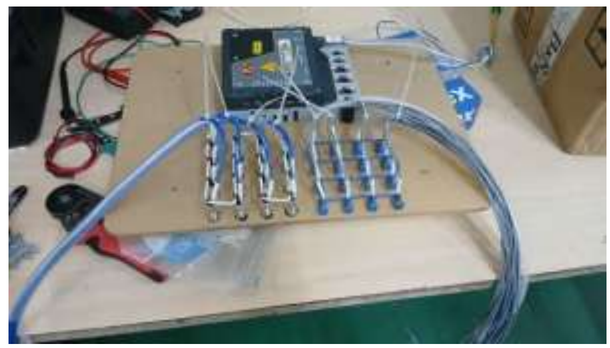

Fig. 4. Internal power and control section (MCB, 24 V DC SMPS, terminals and integrated controller on DIN rail).

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Fig. 5. Integrated controller interfaces (POWERLINK, Ethernet, X2X, USB) and the labelled I/O wiring harness.

I. RESULTS AND DISCUSSION

A. Results

The developed FFS demonstration platform was tested under different operating conditions to verify the functionality of the PLC program and the interaction between the HMI, toggle-switch inputs, and LED outputs. During testing, the system remained in the idle condition until a start command was issued. Once activated, the controller continuously monitored the input states and executed the programmed sequence accordingly.

Multiple test cycles were performed by changing the status of the toggle switches representing different machine conditions. The corresponding LED outputs responded correctly to the programmed logic, indicating operations such as film feeding, filling, sealing, and cutting. The response of the outputs was consistent across repeated trials.

The emergency-stop function was also tested to verify safety operation. When activated, all outputs were immediately deactivated and the system returned to a safe state. The HMI successfully displayed system status information and allowed basic operator interaction during testing.

The observed results confirmed that the developed platform can effectively demonstrate the operational sequence of a Form-Fill-Seal machine while maintaining a safe low-voltage environment suitable for laboratory and educational use.

B. Discussion

The developed platform successfully demonstrates how PLC-based automation can be used to control a packaging process. Although the system does not include actual motors, heaters, or production-line sensors, it accurately reproduces the logical sequence followed in a typical Form-Fill-Seal machine. This approach allows users to understand machine operation without exposure to mechanical hazards or high-temperature sealing elements.

One advantage of the platform is its simplicity and portability. The use of toggle switches to represent machine inputs and LED indicators to represent outputs makes the sequence easy to understand during demonstrations and laboratory sessions. In addition, the integration of the PLC and HMI provides exposure to industrial automation hardware commonly used in manufacturing environments.

The present implementation focuses primarily on control logic demonstration. As a result, real-time process feedback and physical packaging operations are not included. Nevertheless, the platform provides a practical foundation for studying PLC programming, HMI development, industrial wiring practices, and machine-sequence control.

II. CONCLUSION AND FUTURE SCOPE

A. Conclusion

A PLC-HMI based Form-Fill-Seal demonstration platform was successfully designed and implemented. The developed system reproduces the logical sequence of film feeding, filling, sealing, and cutting through simulated inputs and outputs while operating safely at 24 V DC. Testing confirmed reliable operation of the programmed sequence as well as correct response to start, stop, and emergency conditions.

The project provided practical experience in PLC programming, HMI configuration, electrical panel design, wiring, and industrial automation concepts. The developed platform can be used as a demonstration tool for understanding the control principles used in industrial packaging systems.

B. Future Scope

The platform can be developed toward a fully functional prototype by integrating real sensors such as proximity sensors and limit switches for genuine feedback; adding motors or servo systems for actual film feeding and movement; extending the HMI for real-time monitoring and parameter control; adding IoT or SCADA connectivity for remote monitoring and data analysis; and strengthening safety through interlocks and fault-detection mechanisms. These enhancements would transform the demonstration kit into a fully functional industrial FFS prototype.

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