IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.67

Volume 5, Issue 1, March 2025

Design and Implementation of an Automated Soft Drink Manufacturing and Packaging System using Beckhoff PLC

Yagnesh R Thakar[1], Devansh V Desai[2], Chirag S. Dalal[3], Himanshu Kumar R. Patel[4]

B.Tech4th year Students, Instrumentation and Control[1,2]

Associate Professor, Instrumentation and Control[3]

Assistant Professor, Instrumentation and Control[4]

Dharmsinh Desai University, Nadiad, Gujarat, India

Abstract: *This paper describes the automation of a soft drink manufacturing/packaging plant with Beckhoff PLC technology [2]. It includes steps such as mixing, bottling, capping, labeling, and carton packing for accurate process control [6]. The PLC programming is done in Structured Text, and this makes for modularity and scalability [3]. To gain more safety and reliability, several interlocks and sensors were added to the system [5]. It also features an emergency stop operation to quit operations in case of malfunction [5]. The Beckhoff PLC was selected over alternative PLCs due to its superior functions such as high-speed processing, EtherCAT communication, and flexible automation control [2]. Also, its modularity and economy make it an ideal choice for industrial automation [8]. This paper talks about aspects such as system architecture, operational workflow, and technical comparisons with an emphasis on the efficiency gains in automated beverage production [7]. The paper also gives specifications of why Beckhoff was chosen over traditional PLCs and discusses its classification as a soft PLC [2].*

Keywords: Automation, Beckhoff PLC, Structured Text, Soft Drink Manufacturing, EtherCAT, Industrial Automation, Packaging Process

I. INTRODUCTION

Automation is becoming increasingly important in modern manufacturing, raising efficiency, reliability, and safety. The soft drink industry is largely dependent on automated systems operating repetitive routines that minimize human errors while delivering consistency of quality [1]. This study is a case study of the design and implementation of an automated soft drink manufacturing and bottling plant using a Beckhoff PLC. The system is made up of processes such as mixing, filling, capping, labeling, and packing, all done in Structured Text programming [3]. Installation with interlocks, sensors, and emergency stop function guaranteed operational safety and reliability [5]. The Beckhoff PLC has been justified for its high-speed processing, real-time control, and EtherCAT communication, thus making the automation fast [2].

II. BLOCK DIAGRAM

PROCESS DESCRIPTIONS

- Mixing: The procedure starts when the operator presses the start button, thereby operating the mixer motor, which combines the ingredients for 10 seconds [6].
- Conveyor Movement: After the mixing operation, the conveyor carries the bottles toward the filling station for 5 seconds [6].
- Filling: When the bottle sensor detects a bottle, the filling valve is opened for 5 seconds [5].
- Capping: After the filling process is complete, the bottle is moved to the capping station where it is capped and sealed [5].
- Labeling: After the label sensor has confirmed that labeling is achieved, the labeled bottle is now advanced for packing [5].

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 1, March 2025

- Packing: Packing six bottles into a carton activates the carton conveyor, moving them into packaging [7].

- Fig.1. Flowchart of the soft drink manufacturing and packaging process

III. INTERLOCKS AND SAFETY FEATURES

- Bottle Sensor Interlock: This feature guarantees the filling valve can be opened for filling only when there is a bottle present [5].
- Cap Sensor Interlock: This ensures operation shall not occur if there is no cap present [5].
- Label Sensor Interlock: This allows only bottles that have been properly labeled to advance to the packing stage [5].
- Carton Counter: This counts six bottles before activating the carton conveyor [7].
- Emergency Stop: As and when this function is triggered, all actions cease inthe system, thereafter resets the whole system [5].

IV. SOURCE CODE

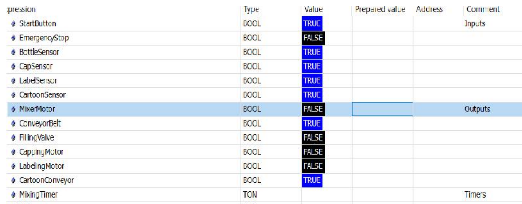
```
PROGRAM MAIN
VAR
 (* Inputs *)
  StartButton: BOOL;
  EmergencyStop: BOOL;
  BottleSensor: BOOL;
  CapSensor: BOOL;
  LabelSensor: BOOL;
  CartoonSensor; BOOL;
  (* Outputs *)
  MixerMotor : BOOL := FALSE;
  ConveyorBelt : BOOL := FALSE;
  FillingValve : BOOL := FALSE;
  CappingMotor : BOOL := FALSE;
  LabelingMotor : BOOL := FALSE;
  CartoonConveyor : BOOL := FALSE;
  (* Timers *)
  MixingTimer: TON;
  FillingTimer: TON;
  ConveyorTimer: TON;
  (* Counters *)
```

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 1, March 2025

```
  BottleCounter : INT := 0;
  CartoonCounter : INT := 0;
END_VAR
(* Start of the Process*)
IF StartButton THEN
  MixerMotor := TRUE;
  MixingTimer(IN := TRUE, PT := T#10S);
END_IF;
IF MixingTimer.Q THEN
  MixerMotor := FALSE;
  ConveyorBelt := TRUE;
  ConveyorTimer(IN := TRUE, PT := T#5S);
END_IF;
IF ConveyorTimer.Q THEN
  BottleSensor := TRUE;
  ConveyorTimer(IN := FALSE);
END_IF;
(* When bottle is detected, start filling *)
IF BottleSensor THEN
  FillingValve := TRUE;
  FillingTimer(IN := TRUE, PT := T#5S);
END_IF;
IF FillingTimer.Q THEN
  FillingValve := FALSE;
  CappingMotor := TRUE;
END_IF;
IF CapSensor THEN
  CappingMotor := FALSE;
  LabelingMotor := TRUE;
END_IF;
IF LabelSensor THEN
  LabelingMotor := FALSE;
  BottleCounter := BottleCounter + 1;
END_IF;
IF BottleCounter = 6 THEN
  CartoonConveyor := TRUE;
  BottleCounter := 0;
  CartoonCounter := CartoonCounter + 1;
END_IF;
IF EmergencyStop AND StartButton THEN
   EmergencyTimer.Q THEN
  MixerMotor := FALSE;
  ConveyorBelt := FALSE;
  FillingValve := FALSE;
  CappingMotor := FALSE;
  LabelingMotor := FALSE;
  CartoonConveyor := FALSE;
  BottleCounter := 0;
  CartoonCounter := 0;
```

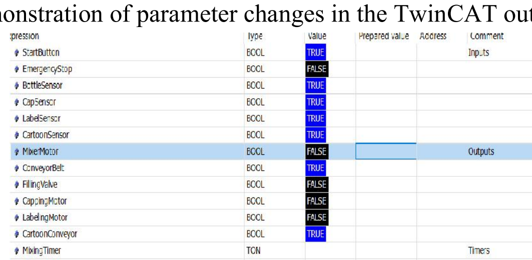
END_IF;

V. RESULT AND DISCUSSION



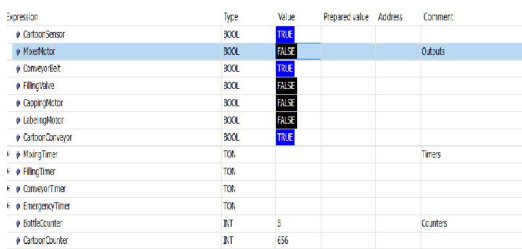
pression	Type	Value	Prepared value	Address	Comment
StartButton	BOOL	TRUE			Inputs
EmergencyStop	BOOL	FALSE			
BottleSensor	BOOL	TRUE			
CapSensor	BOOL	TRUE			
LabelSensor	BOOL	TRUE			
CartoonSensor	BOOL	TRUE			
MixerMotor	BOOL	FALSE			Outputs
ConveyorBelt	BOOL	TRUE			
FillingValve	BOOL	FALSE			
CappingMotor	BOOL	FALSE			
LabelingMotor	BOOL	FALSE			
CartoonConveyor	BOOL	TRUE			
MixingTimer	TON				Timers

Fig.2. Demonstration of parameter changes in the TwinCAT output window



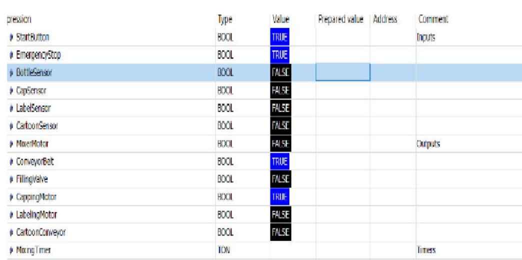
pression	Type	Value	Prepared value	Address	Comment
StartButton	BOOL	TRUE			Inputs
EmergencyStop	BOOL	FALSE			
BottleSensor	BOOL	TRUE			
CapSensor	BOOL	TRUE			
LabelSensor	BOOL	TRUE			
CartoonSensor	BOOL	TRUE			
MixerMotor	BOOL	FALSE			Outputs
ConveyorBelt	BOOL	TRUE			
FillingValve	BOOL	FALSE			
CappingMotor	BOOL	FALSE			
LabelingMotor	BOOL	FALSE			
CartoonConveyor	BOOL	TRUE			
MixingTimer	TON				Timers

Fig.3. Demonstration of parameter changes in the TwinCAT output window



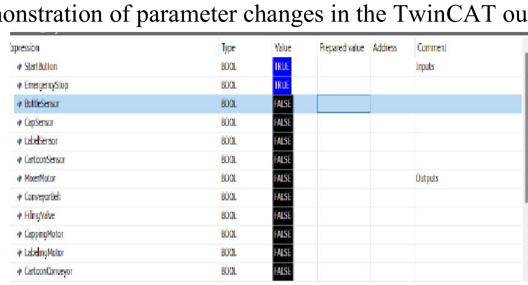
Expression	Type	Value	Prepared value	Address	Comment
CartoonSensor	BOOL	TRUE			
MixerMotor	BOOL	FALSE			Outputs
ConveyorBelt	BOOL	TRUE			
FillingValve	BOOL	FALSE			
CappingMotor	BOOL	FALSE			
LabelingMotor	BOOL	FALSE			
CartoonConveyor	BOOL	TRUE			
MixingTimer	TON				Timers
FillingTimer	TON				
ConveyorTimer	TON				
EmergencyTimer	TON				
BottleCounter	INT	5			Counters
CartoonCounter	INT	656			

Fig.4. Demonstration of parameter changes in the TwinCAT output window



pression	Type	Value	Prepared value	Address	Comment
StartButton	BOOL	TRUE			Inputs
EmergencyStop	BOOL	TRUE			
BottleSensor	BOOL	FALSE			
CapSensor	BOOL	FALSE			
LabelSensor	BOOL	FALSE			
CartoonSensor	BOOL	FALSE			
MixerMotor	BOOL	FALSE			Outputs
ConveyorBelt	BOOL	TRUE			
FillingValve	BOOL	FALSE			
CappingMotor	BOOL	TRUE			
LabelingMotor	BOOL	FALSE			
CartoonConveyor	BOOL	FALSE			
MixingTimer	TON				Timers

Fig.5. Demonstration of parameter changes in the TwinCAT output window



pression	Type	Value	Prepared value	Address	Comment
StartButton	BOOL	TRUE			Inputs
EmergencyStop	BOOL	TRUE			
BottleSensor	BOOL	FALSE			
CapSensor	BOOL	FALSE			
LabelSensor	BOOL	FALSE			
CartoonSensor	BOOL	FALSE			
MixerMotor	BOOL	FALSE			Outputs
ConveyorBelt	BOOL	FALSE			
FillingValve	BOOL	FALSE			
CappingMotor	BOOL	FALSE			
LabelingMotor	BOOL	FALSE			
CartoonConveyor	BOOL	FALSE			

Fig.6. Demonstration of parameter changes in the TwinCAT output window

The automated equipment introduced manages to ensure both correct and effective soft drink production. The results show:

- Maximum Production: The filling of each bottle takes less than 5 seconds, and every step of the packaging process aims to reduce idle time [6].
- Correct Counting of Bottles: Six bottles are packed and the system counts to six. The carton conveyor starts moving as soon as the sixth bottle is identified [7].
- Reduction in Rate of Mistakes: Only washed, capped, and labeled bottles of soft drink are allowed to exit the bottle washing and sealing machine, greatly reducing any chances of mistakes [5].
- Worst Case Scenario Protocol: In cases of uncertainty, sensor failure, or system failure, the emergency stop procedure has narrowed the scope of risk by shutting down all operations within 10 seconds [5].
- Expansion and Flexibility: Expansion and further modifications to increase productivity or the speed of production are easy after installing the Beckhoff PLC [2].

VI. JUSTIFICATION FOR SELECTION OF BECKHOFF PLC AND SOFT PLC APPROACH

The choice of Beckhoff PLC vs conventional PLCs stems from its improved execution and technological sophistication, and the flexibility it provides in the domain of industrial automation. In contrast to standard hardware-based PLCs, the Beckhoff PLC operates as a soft PLC that runs on an industrial PC, providing unique opportunities to its user,including enhanced computing power, cost-effectiveness, and scalability.

VII. ADVATAGES OF BECKHOFF PLC OVER TRADITIONAL PLCs

1. Improved Processing Speed: Unlike traditional PLCs that use microcontroller architectures, Beckhoff PLC uses an industrial PC, which provides faster execution of automation functions [2].
2. Broader Option for Programming: Beckhoff supports a variety of programming languages such as Structured Text, Ladder Logic, C++, and Python, to name a few, allowing a faster development time for automation systems [3].
3. Protocols for Communication EtherCAT: The application of EtherCAT technology assures rapid and deterministic communication ideal for performing the complex automation tasks which require a higher level of accuracy and cooperation [2].
4. Low Cost Together with High Flexibility: With the use of industrial PCs, Beckhoff PLC eliminates the need for costly proprietary PLC hardware as it provides a modular and scalable system, resulting in lower overall system costs [4].
5. Accuracy and Performance Reliability in Real Time: The specialized Soft PLC architecture can yield deterministic real-time performance. The system performs accurately during time-sensitive processes such as filling, capping, and packaging [2].

VIII. CONCLUSION

The introduction into the market of an industrial beverage manufacturing and packaging process automation, operated by Beckhoff PLC, has truly improved performance and dependability in industrial automation applications. Thanks to structured text programming, interlocks, and sensors, the system instills a complete guarantee that performing a process will be accurate. Unlike a conventional PLC, Beckhoff PLC offers such advanced features as high-speed EtherCAT communication, modularity, and flexibility. In addition to the implementation of the emergency stop function, safety is enhanced, and industrial accidents are lessened. The evidence suggests that Beckhoff PLC is an affordable, efficient, and expandable option for the automation of beverage production with little human intervention and maximum production efficiency.

IX. ACKNOWLEDGMENT

The authors would like to thank Prof. Chirag S Dalal, Associate Professor, Department of Instrumentation and Control Engineering, Dharmsinh Desai University, and Dr.(Prof.) Himanshu Kumar R. Patel, Assistant Professor, Department of Instrumentation and Control Engineering, for guiding them through the entire project and providing them with ideas to make the project a success.

REFERENCES

[1] J. Smith and P. Brown, "Automation in Beverage Production: A PLC-Based Approach," Journal of Industrial Automation, vol. 34, no. 2, pp. 45-58, 2021.

[2] Beckhoff Automation GmbH, "Technical Specifications of TwinCAT and EtherCAT," Beckhoff White Paper, 2020.

[3] R. Patel and M. Khan, "Structured Text Programming for Industrial Automation," International Conference on Control Systems Engineering, 2019.

[4] Siemens AG, "Comparison of PLC Architectures: Traditional vs. Soft PLCs," Siemens Technical Report, 2021.

[5] T. Williams, "Sensor Integration in Automated Packaging Systems," Automation Today Journal, vol. 29, no. 4, pp. 112-124, 2020.

[6] K. Johnson, "Conveyor Control Systems in Manufacturing," IEEE Transactions on Industrial Electronics, vol. 67, no. 6, pp. 1234-1245, 2020.

[7] M. Gupta, "Optimizing the Bottle Filling Process using PLCs," Journal of Advanced Manufacturing Technology, vol. 12, no. 3, pp. 78-89, 2022.

[8] Y. Zhao, "Industrial IoT and Predictive Maintenance in Beverage Manufacturing," IEEE Internet of Things Journal, vol. 9, no. 5, pp. 2500-2512, 2021.