Design of an Automatic Wood Cutting Conveyor Simulation with a Programmable Logic Controller

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Abstract
This study aims to design and simulate an automated wood cutting conveyor system using a Programmable Logic Controller (PLC) to enhance productivity and consistency in wood production. The research methodology includes system requirements analysis, hardware and software design, and simulation using PLC software. Key components such as the conveyor, motor, sensors, and cutting tools were identified to design the control circuit within the PLC. The simulation results show that this system can increase production speed and allows integration with other automation systems, thus improving operational efficiency. The simulation has demonstrated the system's effectiveness in boosting efficiency. It highlights the importance of timing in each part of the process: conveyor motor activation within 10 milliseconds, wood transfer within 10 seconds, cutting pause of 2-3 seconds, and cutting duration of 1-2 seconds, with a stop button response time in milliseconds enabling safe process termination.

Keywords: Conveyor, Wood, Programmable Logic Controller (PLC), Productivity, Efficiency

Introduction

The manufacturing industry plays a crucial role in economic development, where innovation serves as a primary driver for increased efficiency and productivity. In the context of wood processing, automated cutting technology has become a research focus aimed at enhancing accuracy and reducing human error[1]. The transformation from manual processes to automation not only lowers labor costs but also increases throughput and results in a faster Return on Investment (ROI)[2]. Previous studies have shown that the use of automation systems in wood processing industries, such as automatic conveyor systems, can significantly boost production efficiency[3]. The implementation of Human-Machine Interface (HMI) in automation systems can improve ease of control and minimize the risk of human error[4]. Furthermore, a study demonstrated that the use of Programmable Logic Controllers (PLC) to control sensors and actuators in wood cutting systems can provide high precision in material cutting[5].

The simulation methods employed in this research refer to approaches used by several previous researchers, such as the use of software for simulating automation process control[6].

For instance, the study conducted utilized OutSeal Studio to design ladder logic on PLCs, which proved effective in automating various industrial processes, including wood cutting[7]. This research presents a simulation of an Automated Wood Cutting Conveyor designed to enhance efficiency and accuracy in wood processing[8]. This simulation involves measuring the length of the wood to be cut and controlling it through a PLC, with the integration of photoelectric sensors and cutting actuators. The literature review indicates that this approach not only enhances process reliability but also provides a competitive advantage in the furniture manufacturing and wood processing industry.

Methodology

The system design involved careful selection of components such as photoelectric sensors, rotary encoders, and actuators. Subsequently, ladder logic programming was developed using specialized software to control the PLC[9], [10]. The implementation of a Human-Machine Interface (HMI) was also carried out to facilitate interaction between the operator and the system, as shown in Figure 1.

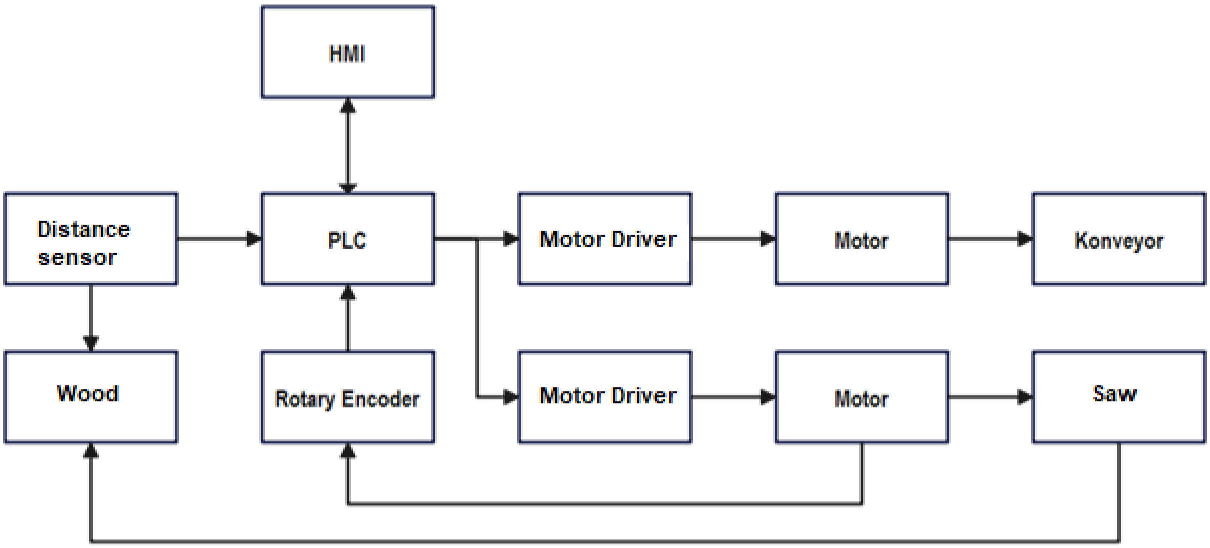

Figure 1. Block diagram system

The distance sensor functions to measure the length of the wood to be cut and sends signals to the PLC. The rotary encoder measures the speed and position of the conveyor, transmitting this information to the PLC to ensure that the wood is cut at the correct position[11], [12]. The PLC, as the control center, receives signals from both the distance sensor and the rotary encoder, processes the control logic, and sends command signals to the motor drive[3], [13], [14].

The motor drive receives control signals from the PLC and adjusts the power supplied to the motor, which moves the conveyor to position the wood correctly for cutting. Once the wood is in the appropriate position, the motor activates the cutting tool to cut the wood to the desired size. This workflow allows for an automated and precise wood cutting process with efficient coordination among all the involved components[15].

A. Ladder Diagram

The Programmable Logic Controller (PLC) controls machinery and industrial processes, such as the wood cutting conveyor, with a ladder program that ensures efficient and safe wood cutting[16], [17], [18]. Its main components include photoelectric sensors to detect wood, push buttons to start/stop the process, motors to drive the conveyor, and relays/actuators to activate the cutting blade. A timer regulates the delay between conveyor operation and cutting, while a counter tracks the number of pieces cut. The operation begins with the start button, the sensor detects the wood, the motor moves the wood, and the sensor stops the motor. The timer activates before the relay/actuator lowers the blade, after which the motor moves the wood again. The process stops with the stop button or after a certain number of cuts.

Results and Discussion

In the simulation, the timing used for each part of the process is crucial to ensure smooth operation. After the start button is pressed, the conveyor motor is activated within milliseconds and begins moving the wood to the cutting position. The time required to move the wood depends on the conveyor length and motor speed. With a conveyor length of 2 meters and a motor speed of 0.2 meters per second, the time needed is approximately 10 seconds. Once the wood reaches the cutting position, the photoelectric sensor detects its presence and sends a signal to the PLC within milliseconds.

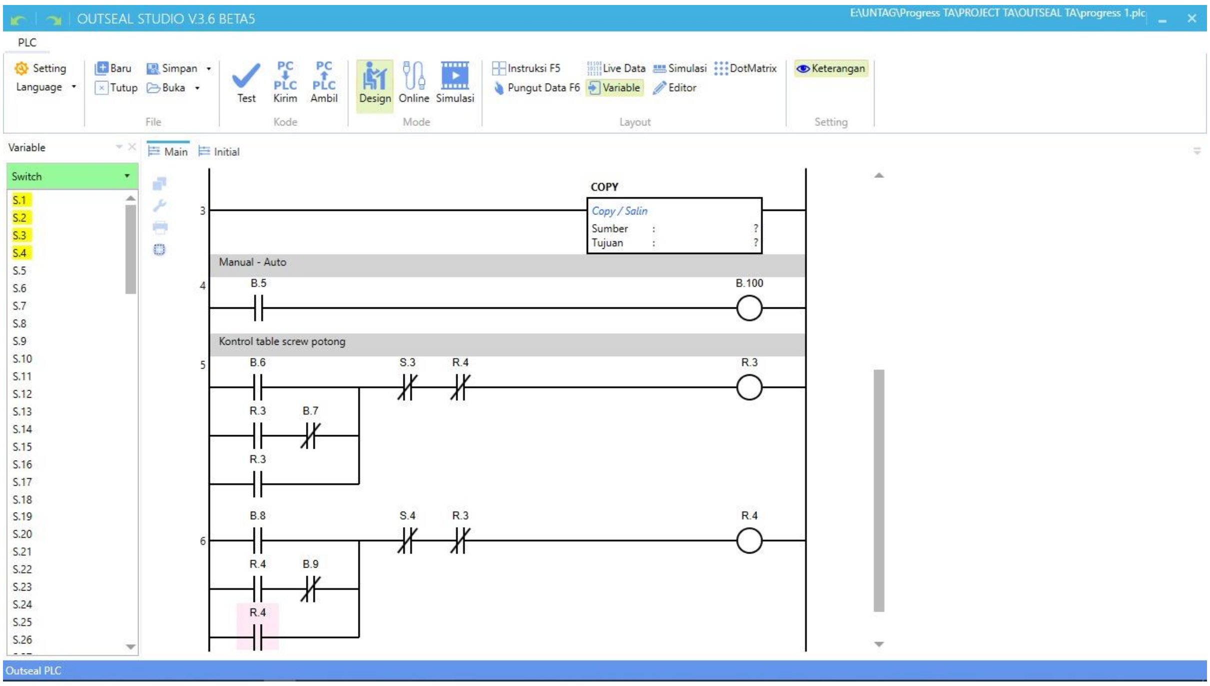

Figure 2. Cutting Table Control Simulation

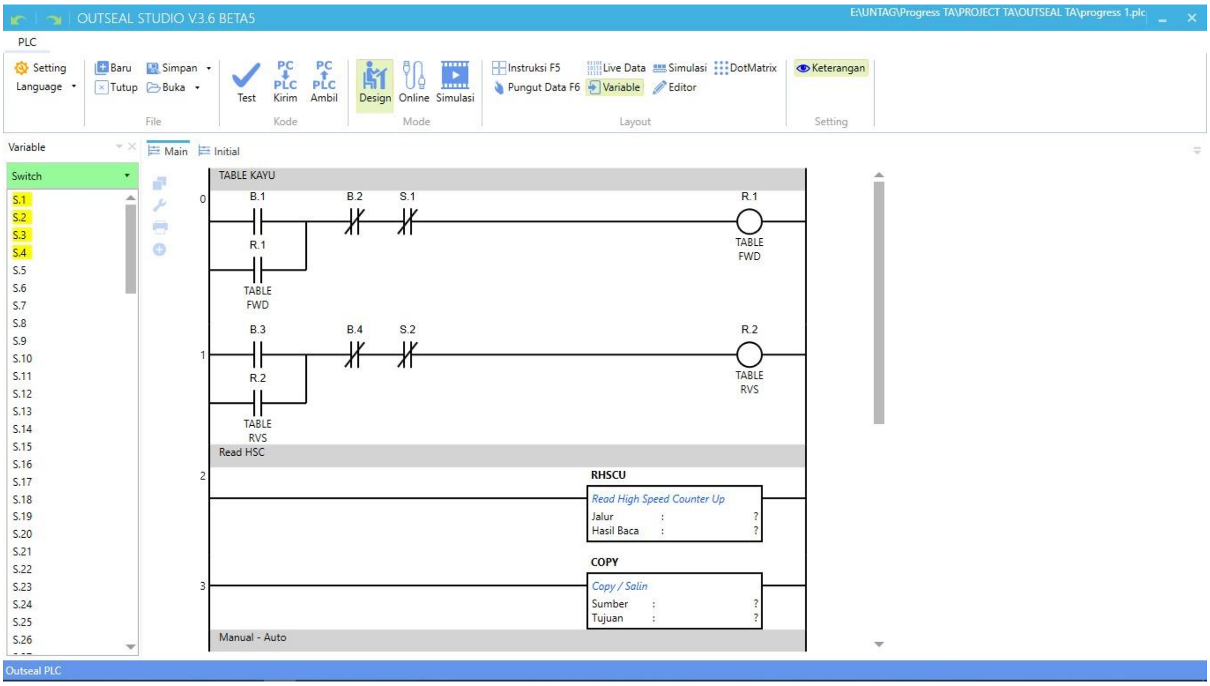

Figure 3. Speed Control Simulation

After the sensor detects the wood, a timer is activated to provide a delay before the cutting blade is engaged. This delay can be adjusted, for example, to 2-3 seconds, to ensure the wood is stable before cutting. The cutting blade is activated 1-2 seconds after the timer finishes. After cutting, the relay/actuator is deactivated, and the conveyor motor resumes moving the cut wood and prepares the next piece. This simulation helps ensure the correct timing for each step before actual implementation.

The simulation program was conducted several times to generate a comprehensive set of narrative statistical data. Each iteration provided valuable insights into the wood cutting process, allowing for a detailed analysis of various components involved. By running the simulation multiple times, we were able to capture variations in timing, efficiency, and overall performance.

The results from these repeated trials highlighted consistent trends in the operational efficiency of the wood transfer, detection, and cutting stages. Each cycle revealed the effectiveness of the conveyor system, with a stable transfer time of 10 seconds, and the rapid response of the photoelectric sensor, which consistently detected wood in just 0.01 seconds.

Moreover, the controlled delay before cutting, averaging 2.5 seconds, ensured that the wood was adequately stabilized, significantly reducing the risk of inaccuracies during the cutting phase. The activation of the cutting knife, with an average time of 1.5 seconds, further demonstrated the system's responsiveness and precision.

By analyzing the cumulative data from multiple simulations, we gained a clearer understanding of the process dynamics and identified potential areas for optimization. This iterative approach not only reinforced the importance of precise timing across each component but also underscored the need for continuous monitoring and adjustments to enhance both efficiency and output quality in the wood cutting operation.

Table 1. Result Simulation

Process Component	Detail	Time (seconds)
1. Wood Transfer Time	Conveyor Length	10
	Motor Speed	0.2 m/s
	Total Time	**10**
2. Sensor Detection Time	Detection Time	0.01
	Total Time	**0.01**
3. Delay Time Before Cutting	Minimum Delay	2
	Maximum Delay	3
	Average Delay	2.5
	Total Time (Average)	**2.5**
4. Cutting Knife Activation Time	Minimum Activation Time	1
	Maximum Activation Time	2
	Average Activation	1.5
	Total Time (Average)	**1.5**
5. Wood Transfer Time After Cutting	Transfer Time	5
	Total Time	**5**
Total Time for One Cycle		**19.01**

Conclusion

The simulation results reveal an efficient and well-structured wood cutting process, with each cycle lasting 19.01 seconds. Effective logistics are highlighted by a consistent 10-second transfer time for moving wood to the cutting area. The photoelectric sensor's rapid 0.01-second detection time ensures immediate responses, minimizing delays. A 2.5-second pre-cutting delay stabilizes the operation, reducing inaccuracies, while the cutting knife activation time of 1.5 seconds allows for timely initiation without compromising material integrity. Overall, this cycle time paves the way for further optimization in production efficiency.

Acknowledgments

We would like to express our deepest gratitude to LPPM Universitas 17 Agustus 1945 Surabaya for their support and resources, as well as to all data providers and respondents for their invaluable contributions to this research.

References

[1] G. A. Taher, Y. Howlader, A. Rabbi, and F. A. Touqir, ‘Automation of Material Handling with Bucket Elevator and Belt Conveyor’, vol. 4, no. 3, 2014.

[2] M. P. Brundage, Q. Chang, J. Zou, Y. Li, J. Arinez, and G. Xiao, ‘Energy economics in the manufacturing industry: A return on investment strategy’, *Energy*, vol. 93, pp. 1426–1435, Dec. 2015, doi: 10.1016/j.energy.2015.10.038.

[3] D. S. V. Siva Vardhan and Y. S. Narayan, 'Development of an automatic monitoring and control system for the objects on the conveyor belt', in *2015 International Conference on Man and Machine Interfacing (MAMI)*, Bhubaneswar: IEEE, Dec. 2015, pp. 1–6. doi: 10.1109/MAMI.2015.7456594.

[4] H. Meddeb, Z. Abdellaoui, and O. Ezzine, 'HUMAN MACHINE INTERFACE DESIGN OF INDUSTRIAL AUTOMATED MACHINE USING SIMATIC SCADA SYSTEM'.

[5] D. N. B. Saad, 'PLC-Controlled of a Conveyor System I'.

[6] S. Yilmaz, B. Cakir, A. Gedik, and H. Dincer, 'Speed control of a conveyor system by means of fuzzy control aided PLC', in *ISIE '99. Proceedings of the IEEE International Symposium on Industrial Electronics (Cat. No.99TH8465)*, Bled, Slovenia: IEEE, 1999, pp. 1328–1332. doi: 10.1109/ISIE.1999.796896.

[7] W. C. Ningrat, 'Implementation of PLC Outseal as a Controller of Ammonia Gas Circulation in Chicken Coops with HMI Modbus Monitoring', *Indones. Vocat. Res. J.*, vol. 2, no. 2, Art. no. 2, Apr. 2023.

[8] J. Liu, L. Kong, J. Zheng, Z. Ding, L. Feng, and Y. Lv, 'Automatic Sorting System for Wood Diameter Grades', vol. 12, 2024.

[9] R. C. Mhlanga, T. Mushiri, and C. Mbohwa, 'Design for manufacture and assembly of an automated wood cutter: Case for developing country'.

[10] A. Dahman and K. Khamayseh, 'Design of Wedge Wood cutting Machine'.

[11] B. Leng and W. Hu, 'Design and implementation of sawdust dust removal system based on PLC control', in *2020 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE)*, Harbin, China: IEEE, Dec. 2020, pp. 879–882. doi: 10.1109/ICMCCE51767.2020.00193.

[12] V. Daund, R. Kadam, S. Patil, T. Tikudave, and D. Pawar, 'Design of Integrated PLC with SCADA Systems for Grooving Machine', in *2023 7th International Conference On Computing, Communication, Control And Automation (ICCUBEA)*, Pune, India: IEEE, Aug. 2023, pp. 1–6. doi: 10.1109/ICCUBEA58933.2023.10392264.

[13] S. Sahai, 'Development of PLC Based Control System for Automatic Shearing Machine', vol. 3, no. 03.

[14] E. Mainardi, M. Bonfe, and M. Golfieri, 'Fuzzy Controller for an Air Conveyor Bottling Plant'.

[15] N. Fil, 'Method of Selection of Programmable Logic Controller in Conditions of Fuzzy Information', in *2023 IEEE 4th KhPI Week on Advanced Technology (KhPIWeek)*, Kharkiv, Ukraine: IEEE, Oct. 2023, pp. 1–4. doi: 10.1109/KhPIWeek61412.2023.10312848.

[16] I. L. e Lopes, L. A. Araújo, E. N. Miranda, T. A. Bastos, L. R. Gomide, and G. P. Castro, 'A comparative approach of methods to estimate machine productivity in wood cutting', *Int. J. For. Eng.*, vol. 33, no. 1, pp. 43–55, Jan. 2022, doi: 10.1080/14942119.2021.1952520.

[17] R. Jiroušek, R. Klvac, and A. Skoupý, 'Productivity and costs of the mechanised cut-to-length wood harvesting system in clear-felling operations', *J. For. Sci.*, vol. 53, pp. 476–482, Oct. 2007, doi: 10.17221/2088-JFS.

[18] H. M. Shukla and M. M. Gupta, 'A comprehensive approach to enhance wood cutting productivity: Integration of spherical fuzzy DEMATEL and artificial neural networks', *Proc. Inst. Mech. Eng. Part E J. Process Mech. Eng.*, p. 09544089241253083, May 2024, doi: 10.1177/09544089241253083.