Pots Filling Production Line

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***Abstract*—This study involves the integration of an industrial control system (ICS) into a pneumatically actuated production line for filling and covering pots. The newly implemented control system encompasses sensors, a Programmable Logic Controller (PLC), and a Human Machine Interface (HMI) screen. This ICS serves as the central supervisory and operational hub, guiding the entire production process, including pot insertion, filling, tin foil and plastic cover placement, and product retrieval along the production track. The control system offers a user-friendly interface through the HMI screen, allowing operators to control and monitor the production line. Users can issue instructions to the PLC and access real-time data collected from the sensors. The system supports both automatic and manual operation modes, the latter being particularly useful for identifying and addressing faults. Additionally, the system's versatility enables it to adapt to various products, requiring only minor parameter adjustments.**

Keywords— PLC, HMI, Industrial control system.

I. Introduction

Manufacturing systems are integrated systems of equipment and people that transform raw materials into finished products. They can be automated or manual, or a mix of both. Automated systems use machines and computers to perform tasks, while manual systems rely on human labor [1]. Manufacturing systems include a variety of equipment, such as production machines, material handling devices, and computer systems. Production machines perform the processing and assembly operations on the raw materials. Material handling devices move the raw materials, parts, and finished products through the system. Computer systems control the equipment and monitor the system's performance [2].

Automation is the use of technology to perform tasks without human intervention. It is implemented using a control system that executes a program of instructions. Automation requires power to operate the control system and the process itself [3], [4].

The automated system consists of three basic components: (1) power, (2) a program of instructions, and (3) a control system to carry out the instructions. The relationship among these components is shown in Fig. 1 [5]–[7].

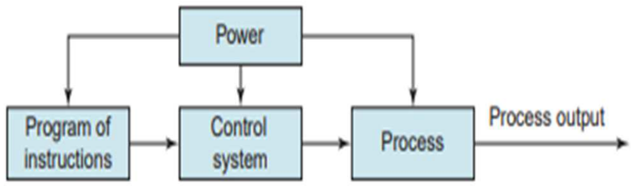

Fig. 1. Elements of an automated system.

Production lines are an important type of manufacturing system for making large quantities of identical or similar products. They are divided into small tasks that are performed efficiently by workers or machines. The two basic types of production lines are manual and automated, but hybrid lines are also common [8]–[11].

A production line comprises a series of workstations, allowing the product to progress sequentially, with each station contributing to the overall manufacturing process, as illustrated in Fig. 2. The production rate of the entire line is determined by the slowest workstation. Workstations operating at a faster pace ultimately is expected to be constrained by this bottleneck station. Typically, products are transferred along the line using conveyors or mechanical transfer devices, although manual lines may involve passing the product from one worker to another. Production lines are commonly linked to mass production, ideal for scenarios with high product quantities and tasks that can be segmented and allocated to individual workstations [12]–[15].

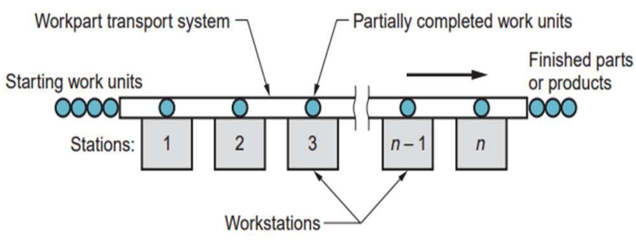

Fig. 2. General configuration of a production line.

The term "Industrial Control System" (ICS) is a broad category that encompasses various control systems, which include systems like Supervisory Control and Data Acquisition (SCADA), Distributed Control Systems (DCS), and smaller configurations like skid-mounted Programmable Logic Controllers (PLC) frequently employed in industrial sectors and critical infrastructure settings. ICSs find applications in a range of industries, including electrical, water management, oil and gas, chemical processing, transportation, pharmaceuticals, pulp and paper, as well as sectors like food and beverage production and discrete manufacturing, such as automotive, aerospace, and durable goods manufacturing [16], [17].

II. POTS FILLING PRODUCTION LINE

This machine shown in Fig. 3, is a rotary production line pneumatically actuated that fills and covers pots of Sauce, hummus, and other products. It was brought from Al-QAISI Factory to be maintained and equipped with an PLC to supervise and control its operation in the required sequence.

Fig. 3. Overview of the pots filling production line.

The production line comprises:

- Body: A metal structure housing a rotating disk with 16 holes for holding pots, spaced at 22.5-degree intervals.
- Motor: An asynchronous induction motor (VEMAT) with specifications: 3.2/3.6 A, 220 V Delta/400 V star, 50 HZ, PF 0.8, 1500 RPM, 2 HP, IP 54. It operates the pot holder disk via a gearbox, stopping it every 22.5 degrees.
- Position Disk: Linked to the pot holder disk, it has 16 screws spaced at 22.5 degrees, representing pot positions.
- Actuators: Eleven double-acting pneumatic actuators, each driven by a 6.2/3.6 A DC electric motor (220 V Delta/400 V star) with speed control via inverters. Split into six workstations:

  a. Pots Insertion Station: Two actuators - one for picking pots and one for lowering them using a vacuum pump.

  b. Filling Station: For filling pots with Hummus, consisting of two actuators - one for drawing Hummus from a tank and one for directing it into pots via a valve.

  c. Tin Foils Covering Station: Features a vertical actuator for picking and placing tin foils on pots, secured by a heater.

  d. Heating Station: Utilizes a vertical actuator with a heater to firmly attach tin foils to pots.

  e. Plastic Covers Station: Incorporates a vertical actuator to pick and position plastic covers on pots, applying pressure for fixation.

  f. Products Output Station: A vertical actuator to raise products above the disk level for removal.

III. METHODOLOGY

This section discusses the process to fabricate the control system of the production line from the beginning to the end of the study.

Overall, this project is following the flow chart from choosing the title, then finding the related literature review for the project given. Then, sketch some designs of the Industrial Control System (ICS) to choose the best design. After the fabrication is finished, the ICS is tested to the production line to get results. Finally, a report documentation is written to describe all the process since the beginning to the end of the project. Fig. 4 shows the flow chart of this project.

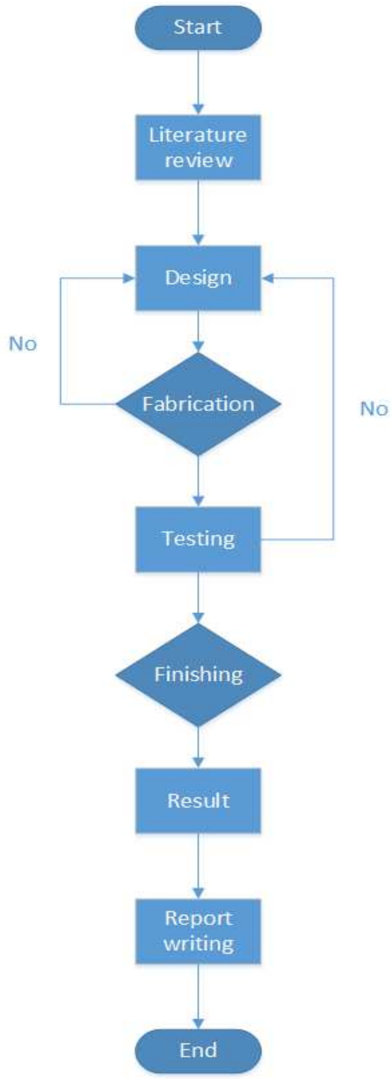

Fig. 4. Methodology flow chart.

The design of the ICS power diagram (wiring diagram) is shown in Fig. 5

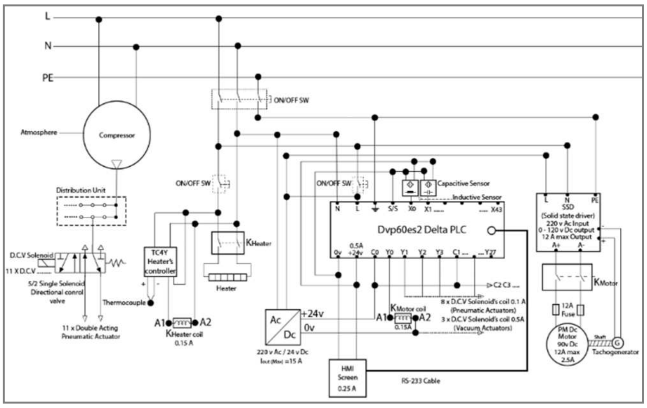

Fig. 5. ICS power diagram (wiring diagram).

PLC programming (Ladder diagram): It has been written using WPLSoft 2.46 program. The main approach taken for programming depends on the less possible number of sensors due to economic reasons and replace these sensors by combinations and sequences of counters and timers. These combinations arrange the operation during starting and finishing (first and last strokes).

HMI screen design & programming: It was designed using DOPSoft 2.00.07 and Photoshop programs due to get a stylish design in addition to its main operation which is represented in giving the possibility to control and supervision the production process.

All components were installed and wired as designed in Fig. 6, using suitable wires according to the components' maximum currents. After that all the components were divided into 3 panels: (1) PLC panel contains the PLC. (2) User panel contains selector switches, heater controller and HMI screen. (3) Power panel contains contactors, motor driver and power converter. These panels are shown in Figures 3.10 (a), (b), (c) respectively.

Fig. 6. ICS panels.

TC4Y Heater's Controller and Solid-State driver 508 were installed according to their manuals, that shown in Fig. 7 and 8 respectively.

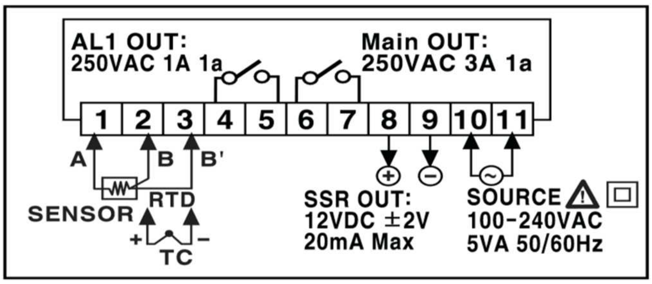

Fig. 7. TC4Y heater's controller wiring diagram.

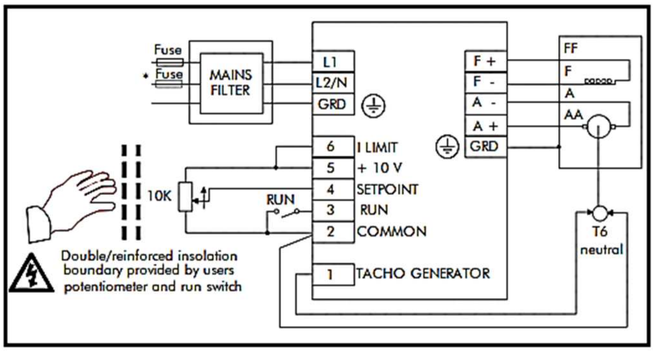

Fig. 8. SSD 508 wiring diagram.

The PLC Ladder diagram has been downloaded to the PLC using M12 to RS-232 Cable with RS-232 to USB converter.

The HMI screen program has been downloaded to the HMI screen using USB 2.0 type A to B converter.

PLC and HMI screen were connected using M12 to RS-232 Cable with RS-232 male to male converter.

The production line was tested, and its timers was calibrated to have the most suitable timers' values that are exactly enough to allow the workstations to finish their operations and gives the less possible production time.

Also, the actuators speeds were calibrated by calibrating the air flow through the flow control valves (FCVs) to make sure that the actuators operate smoothly without hitting the product.

IV. Results

The production line was developed and provided with the following features:

- Its whole operation can be managed and controlled with the ICS which has been installed.
- The ICS is fixable with future changes that can be happened, mainly by editing the PLC program.
- The ICS easily to be maintained, because it has the lowest possible hardware components and wires. In contrast with classic control which can't be easily maintained.
- The production line can be used for multi-products production simply by mechanically replacing the filling workstation, and changing the related timers' values by the HMI screen.
- The whole operation can be supervised and monitored using the HMI screen.
- It produces around 1200 pots per hour.
- The ICS has a very simple HMI screen design to be handled by users.
- The production line price was about 15K NIS (4.1K $) before it has been maintained and provided with the ICS which also costed about 5K NIS (1.4K $). Now its price around 50K - 60K NIS (14K - 16.5K $), as estimated by the owner.
- It has a high production reliability.

- The set of Fig. 9 show the final overview of the production line.

Fig. 9. Final overview of the production line.

V. CHALLEGNES

- The using of Adobe Photoshop CC program to provide a simple and stylish HMI screen design which needed too much time, because DOPSoft 2.00.07 program does not offer good graphical elements.
- Isolating all the components from wetness, since it's a liquids production line. So plastic closed panels were used to contain the hardware components.
- Some faults were faced in detecting the positions of the screws of the position disk. These faults have been solved by replacing the small screws by larger ones.
- The maximum output current of the 24V Dc supply of the PLC is 0.5A Dc which is not enough to supply all the Dc components, so external 24V Dc power supply which is a 220V Ac/24V Dc converter was provided.
- The number of the required number of pots to be produced can't be less than 12 pots – one full stroke (revolute) – because the counter which counts the pots number depends on the last workstation (Products output station).
- The small heater in the tin foils covering station has less power than the main heater in the heating station, so it needs more time to be heated up.

VI. FEASIBILITY STUDY

- High production speed, since it produces 1200 pots/hour, means 600 NIS (165 $)/hour if the benefit was 0.5 NIS/pot (0.14 $/pot).
- Production line fabrication costs about 20K NIS (5.5K $), now its price around 50K - 60K NIS (14K - 16.5K $), as estimated by the owner.
- This project can be implemented in quantities as a business, that gains about 30K NIS/machine (8.2K $/machine).
- Low cost and simple control system, which costed about 5K NIS (1.4K $).
- Needs easy and low cost maintenance.
- Supporting the local production which costs much less than an imported production line in the same features which costs about 100K NIS (27.5K $) as lowest estimates.

VII. CONCLUSIONS AND RECOMMENDATIONS

This study successfully integrated an industrial control system into a pneumatically actuated production line for filling and covering pots. The industrial control system, comprised of sensors, a Programmable Logic Controller, and a Human Machine Interface screen, served as the central supervisory and operational hub for the entire production process, streamlining pot insertion, filling, tin foil and plastic cover placement, and product retrieval along the production track. The industrial control system provides a user-friendly interface through the Human Machine Interface screen, allowing operators to control and monitor the production line in both automatic and manual operation modes. Its versatility and adaptability make it a cost-effective solution for multi-product production, and its simplified hardware components and wiring ensure easy maintenance and high production reliability. This project underscores the potential of automation and control systems to enhance manufacturing processes in various industries while supporting local production and cost savings.

Here are some recommendations for further enhancements and optimizations of the production line:

- Consider adding more sensors to enhance machine reliability and enable automatic fault detection features, although the associated costs should be carefully evaluated.
- Explore the possibility of adding different filling stations to diversify the range of products that can be accommodated by the production line.
- Evaluate the feasibility of incorporating a conveyor belt at the last station (Products output station) to streamline the removal of pots from the production line.
- To address the issue of the required minimum number of pots, consider installing a sensor at the first station (Pots insertion station) for improved pot counting.

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