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Research article

Controllers design for the semi-automation shrimps tempura frying production line

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ABSTRACT

Nowadays, the applications of automatic control systems have been developing very fast in many diversify of the industry fields. One of the most significant industry that is needed to care and focus to develop this automation technology in order to reduce the huge number of workers and increase the productivity is the seafood industries. Normally, the seafood industry has a lot of workers to carry out everything manually. There still remain many research topics relating to this field to help this industry to develop in the trend of 4.0 ages. The semi–automation shrimps Tempura frying production line is a system to make Tempura shrimps with high productivity. The workers simply put the shrimps into the serial of chain frying molds and the system will automatically do the whole production process to produce the completed Tempura shrimps. The whole process to produce Tempura shrimps includes the following steps: (1) Shaping shrimp and cover with powder solution by automatic powder solution spraying system; (2) Complete frying to make the shrimps to be cooked; (3) Oil draining system to remove the remain oil inside the shrimp and the powder cover. Then the finished products will be put into the frozen system to preserve. The whole production line will be separated into 3 main modules: Module 1: The shaping module (first time frying) and powder solution spraying module; Module 2: The deep fry module (second time frying); Module 3: The oil draining module. This paper introduces about the control system for each module and the controller of the whole system to make a complete semi-automation shrimp tempura frying production line.

Some controller technology as On/Off, PID control algorithms are proposed to apply for the whole production line as: speed control of the stainless-steel chain conveyors, temperature control of the cooked tanks, quantitative control of the powder solution amount to be sprayed on the shrimps, the oil draining conveyor speed, the heat and air flow control of the oil draining module.

Key words: Control system, semi – automation, Tempura, fried shrimp, powder solution, spraying system, temperature control, speed control

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LITERATURE REVIEW AND INTRODUCTION

According to Michael M. Blumenthal, Deep – fat frying method is the most important unit operations in both the catering and food processing industries [1]. This system fried shrimp by deep frying method, and this is not a new method, which been used in family food for a long time ago, but according to Don Banks this method only used in industrial and become an independent business since 1890s [2]. Don Banks also informed that there are 6 zones or fryer area: (i) entry, (ii) case hardening, (iii) shape firming, (iv) cooking, (v) finish frying and (vi) takeout. From this area, there are 3 main stages: zone (i) to (iii) can be called stage 1 zone (iv) and (v) is the stage 2 and zone (iv) is the stage 3. Corresponding to 3 main stages, the system has 3 main functional modules that can operate independently: first time frying and pow der solution spaying, second time frying and oil draining. To make the suitable for the whole system, the amount of powder solution spraying should be controlled to match with the speed of the conveyors in module 1 and module 2 and also the fan capacity should be varied according to the type of shrimps. The oil temperature in module 1 and module 2 are adjusted and maintained to match the requirement. In this production line, the required temperature is about 175^{0}C. Besides, in module 1 and 2, there should be an oil filter system operating continued to ensure the pure oil to be used for the frying system. A suitable control system is needed to propose for operating those above functions. In this study, the PID temperature controller is proposed, solenoid valves operate the powder solution injection and inverters control the conveyors speed. Those devices and others module function are connected to a PLC. The most important function of

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controller design for the frying line is the temperature and conveyor speed control. The conventional PID controller has been applied to a wide variety of processes with varying degrees of success. PID controllers generally perform best for processes characterized by linear, low-order dynamics. Advanced control techniques have been studied for application in frying lines in order to optimize the criteria such as the efficiency, nutritive, taste, aesthetic values… According to Timothy A. Haley *et al*, the Self-tuning control may benefit processes where a PID controller works well but requires frequent tuning to maintain acceptable control owing to the effect of immeasurable load disturbances, such as moisture variations in the feedstock of frying processes [3]. Ryszard Rywotycki has also developed a fuzzy logic control system. Fuzzy logic uses vague and imprecise expressions, such as: lower efficiency, lighter color, good consistency, etc. The advantage of this system is the possible easy adjustment of the degree of food frying to individual customer preferences. This control system is suitable for a universal automatic frying line with various raw material and desired properties of fried products matching individual client preferences [4]. According to Don Banks, managing the feedstock requires little expense and pays large returns in both production efficiency and finished product quality [5]. For each shrimp size, the oil temperature and conveyor speed can be set up for optimal quality and then remain essentially unchanged throughout the entire production period. This approach allows the system to operate efficiently with a simple controller while still meeting the customer's criteria. With advances in digital technology, the science of automatic control now offers a wide spectrum of choices for control schemes. However, more than 90% of industrial controllers are still implemented based around PID algorithms, particularly at the lowest levels. According to Kiam Heong Ang with three terms functionally covering treatment to both transient and steady – state response PID control provides the simplest and most efficient solution to many real – word control problem [6]. For this reason, the PID controller is proposed to control the oil temperature. Different type of shrimp needs a different value of temperature, because of that, the oil temperature is very important and controlling the temperature is not an easy problem. In order to control the temperature of oil precisely the system need thermocouples that satisfy precision, time response, safety purpose.... From the paper of Olivier Vitrac *et al*., type K has been used in their research to measure the temperature during the deep frying process [7]. These devices work quite effectively during the research and is proved suitable for deep-frying control system. Because the fryer is too large for one thermocouple to detect, in paper of Olivier Vitrac *et al.,* there are five thermocouples placed at different position and different depth and the value of oil's temperature is the average value of five thermocouples. In the paper about the effect of frying oil on deep – fried of Nagao Totani showed that oil used with high temperature too long has a negative effect on the food, can produce a lot of unhealthy chemicals [8]. It is also the main reason for the unpalatability of the even though it is frozen immediately after fried, this is when the drain oil module involves. The other sections of this document are provided as follows. Section ***Research methodology*** presents the research methodology for constructing the process of automating tempura shrimp frying. The main conveyor system that is used in the system is described in Section ***Conveyor speeds controller design***. Next, sections ***The controller design for module 1, 2 and 3*** focus on the controller design to operate these 3 main modules throughout the system. After that, the results and discussion are presented in Section Results and discussion. Finally, the conclusions of the research topic will be covered in Section ***Conclusion***.

RESEARCH METHODOLOGY

Based on the manual practical process applying in most of the tempura shrimp production in industry, the proposed semi-automation shrimp tempura frying production line has similar stages and procedure as workers doing their frying task in the shrimp production factories. Therefore, the system has working procedure showed in following chart in Figure 1.

The system includes the main modules designed to have completely independent function in order to satisfy the requirement of the companies as well as make it easy to adjust and modify if necessary. Therefore, the control system for each module is designed separately. Frying system include of 3 main modules introduced in the previous section. In module 1, there are some controlled parameters as: conveyor speed, oil temperature, powder solution (which can be called batter) spraying amount, oil filter system. In module 2, the control parameters are conveyor speed, oil temperature, oil filter system. And finally in module 3, the control parameters are conveyor speed, flow speed and heating temperature. The whole system is controlled by PLC.

As shown in Figure 2, the shrimp tempura frying system consists of an independent working block, linked by PLC. The system's circuit is divided into three small groups in order to decrease current wires, make the

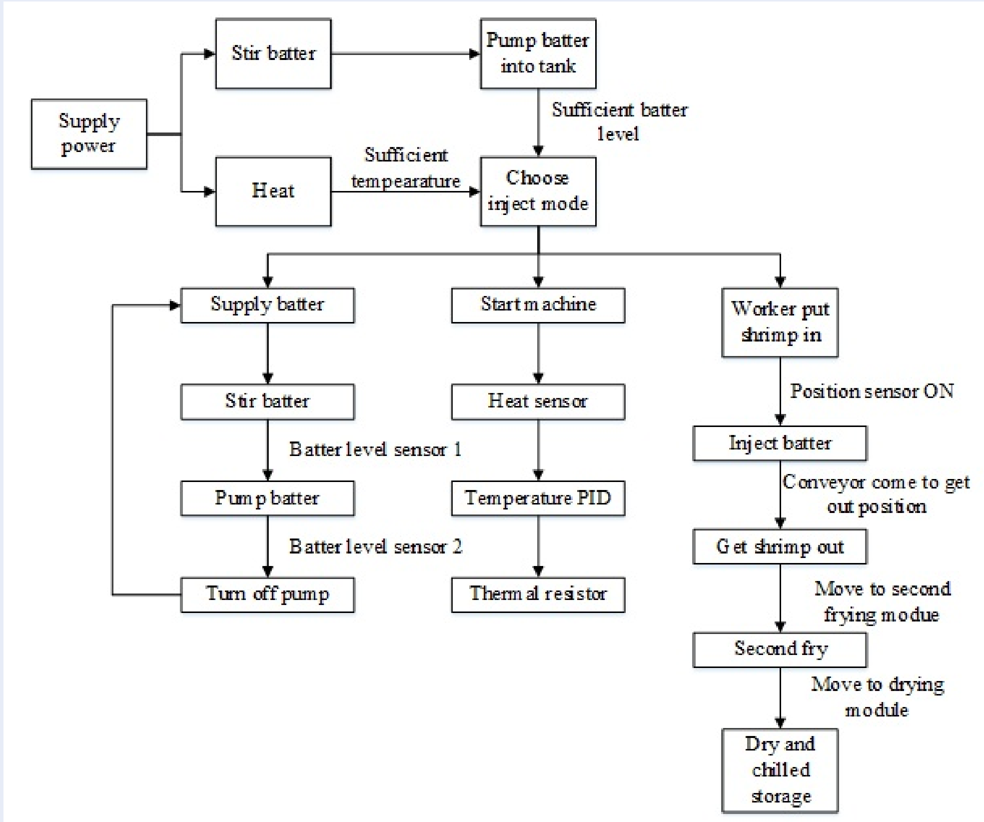

Figure 1: Block diagram for controlling Tempura shrimp frying production line.

system safer, easier to install and maintain. They include two extra circuits consist of Contactor, PID temperature controller and thermal resistor. Another one is main circuit control all electrical systems consist of others electrical equipment: PLC, motor, CB, inverter, level sensor, photoelectric sensor, pump, solenoid valve, oil filter.

Operation procedure of the whole tempura shrimp frying production line is described in the following steps:

Step 1: Turn on power supply, PLC takes the signal and activate power light, temperature control module and powder solution level control module are activated by temperature and powder solution level are sufficient, feedback will be sent to the PLC on the main control circuit. In this process, the powder solution mixer in the tank is activated through "k3" and time setting in the PLC.

Step 2: When there is a signal on PLC allow user to import parameter through input buttons "xn". Then, define the shrimps size, the different size needs different amounts of injected powder solution or others mode such as auto set up parameter by a rheostat.

Step 3: After the switch is activated to "run" mode, the PLC instantly activates all features have been set up such as number of side need to be injected powder solution, motor speed, signal lamps as programmed and set up through contactors, relays, inverters. When PLC receives signal from the conveyor position sensor, it will activate the solenoid valve to inject powder solution amount by setting up the timer. The powder solution pump system will inform PLC through "k8" if the powder solution is pumped or not.

Step 4: In working process, PID temperature controller has been being activated to maintain temperature at set up value, powder solution level control system work when the sensor informs lack of powder solution, the pump automatically pumps powder solution into the tank without PLC signal.

Step 5: Press the "Stop" button, the whole system will stop working.

In order to perform this procedure, the control system is programmed as the following block diagram in Figure 1 above.

All the electrical and control devices will be communicated with each other by the main PLC. There are four parts being controlled as: (1) Adjust the temperature through the PID controller to operate on/off states of the heating resistors. The PID controller (AX4) has the function of auto tuning the parameters of the PID parameters as Kp, Ki and Kd with respect to the sampling temperature signal input to this controller. It will kept the oil temperature at the desired value by output the suitable control signals to the heating resistors via the output control pins connected to the SSR; (2) Observe and control the powder solution level and inject the pressure to ensure that all the shrimp will have the same amount of powder solution (Figure 2); (3) Oil filter system; (4) Control the speed of the conveyor by inverter. The communication of the hardware in the control system is shown in Figure 2.

First, the PLC will check the temperature and the powder solution level and make sure that the machine is ready to work and the worker have to choose shrimp type and inject mode and the rest will be controlled by the system. This issue is introduced in Figure 3.

Input Parameters: The workers choose the types of shrimp, the frying temperature and the speed of the motor.

Sensor system: Include the temperature sensor detect the oil heat, the position sensor which will turn on the powder solution injection module and the powder solution level sensor – detect level of powder solution inside the powder solution box. Thermal resistance will be controlled by PID controller.

CONVEYOR SPEEDS CONTROLLER DESIGN

The system uses inverters to customize the conveyor speed for the shrimp frying molds with respect to the size of shrimps. In addition, the stainless steel net conveyor belt for transporting shrimps from the module 1 to module 2 are also controlled by inverters. As is known, in addition to the function of bringing shrimp to the next module, this conveyor speed also contributes to the flow exchange at the end of module 1, which helps the shrimps move quickly or slowly when passing through the frying process in module 2. This adjustment depends on the speed of the pre-frying mold conveyor, avoiding too much stagnation of shrimp at the end of first time frying process because it will affect the quality of fried shrimp.

In module 1, shrimps will be carried by 2 conveyors, which is operated by 2 separate motors. When the system operates, both motors will be turned ON and can run at different speed by adjusting 2 potentiometers connecting to the inverters of each motor.

Choosing inverter: Because of different type of shrimps needs different amounts of time to fry and that depend on the speed of the motor which is modified through an inverter. Some parameters for choosing inverter: Motor power: 0.75kW; Power supply: 3 – phase 380V; The LS-IG5A inverter family is the most suitable for this system. The control diagram is introduced in Figure 4.

THE CONTROLLER DESIGN FOR MODULE 1

In module 1, the main purpose is not completely frying the shrimp meets the standard, but to form the shape of the shrimp to the standard stature and cover the shrimp with powder solution to make the shrimp tempura.

Temperature control module:

About temperature control process, there are two types of controllers that are commonly used: ON/OFF control and PID control, also there will be other types ON/OFF control module: This is the easiest control module which has been used in a long period of time in industries up to now.

The working principle of this ON/OFF is quite simple as in Figure 5: The controller will output if the measuring ambient temperature exceeds the set value (can operate within the delay range without the set value - if the user has a delay range setting).

With the above special features, the ON / OFF mode control is often applied in large-scale temperature control systems, allowing high over-temperature and little temperature change, for example: Heating control system, refrigerator, fan, ...

PID control mode

PID is the conventional control algorithm that has been used in most of the applications in industries.

Normally, when using a thermostat with the PID control mode, the Auto Tuning function is always included. This function automatically adjusts the Kp, Ki and Kd parameters for the best system response. However, in some special cases, the user still has to control it manually. The application of PID controller mode for temperature is introduced in Figure 6.

When the machine is ON, the temperature sensor will check the temperature of oil in the tank 1 and tank 2. If it does not meet the require temperature of 175^0C, the heat resistance will be turned ON by PLC and then turned OFF when the temperature is satisfied. The temperature controller will tune the value of the PID parameters automatically with respect to the input temperature value reading from the thermocouple Pt100 and the desired temperature of 175^0C.

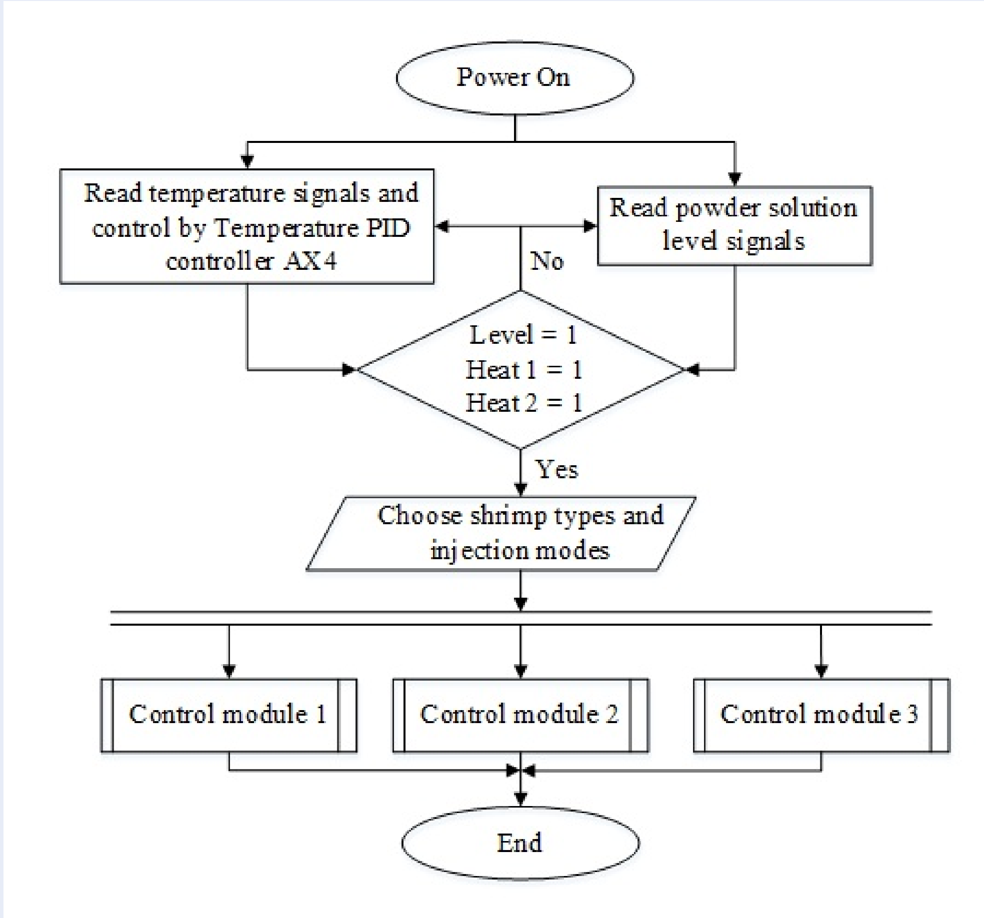

Figure 2: Main program control diagram

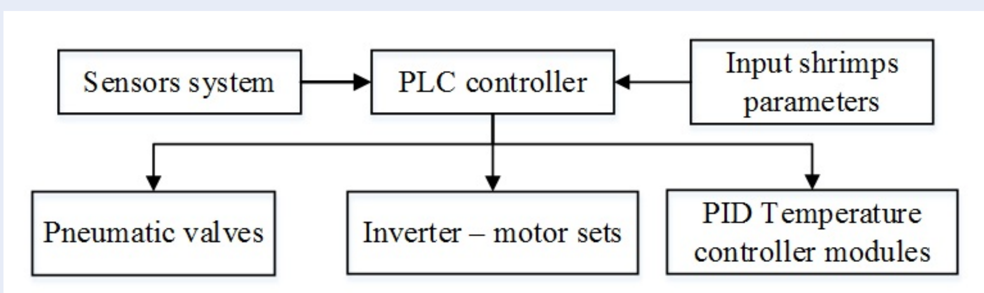

Figure 3: Control system component

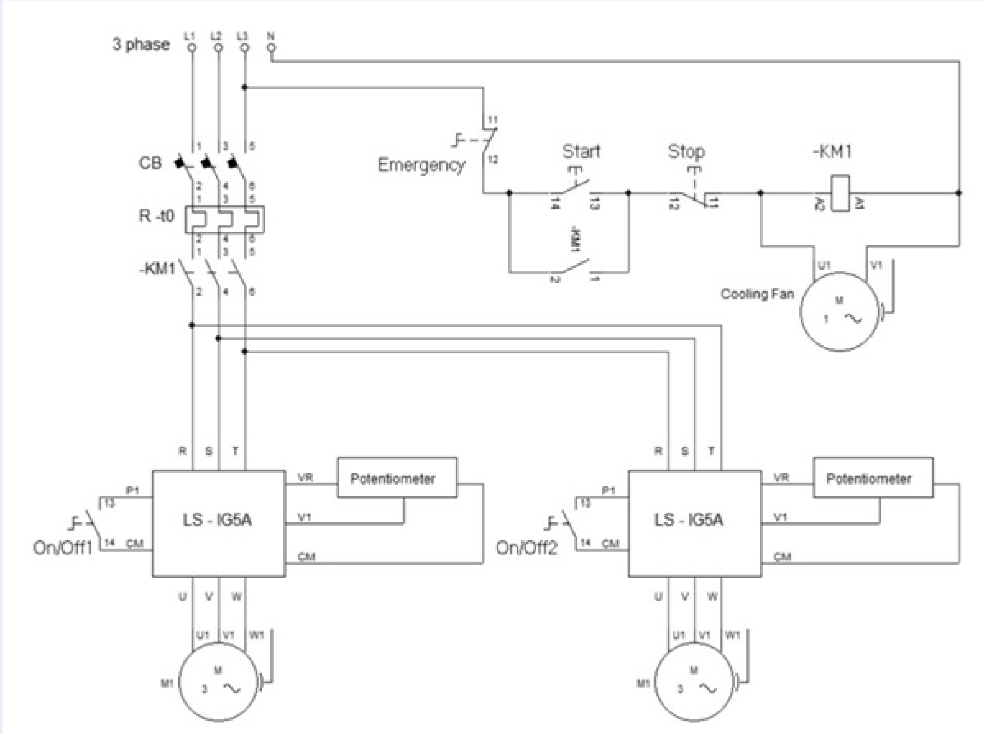

Figure 4: Circuit diagram of the inverter controlling 2 3-phase motors of the 1st powder solution injection assembly

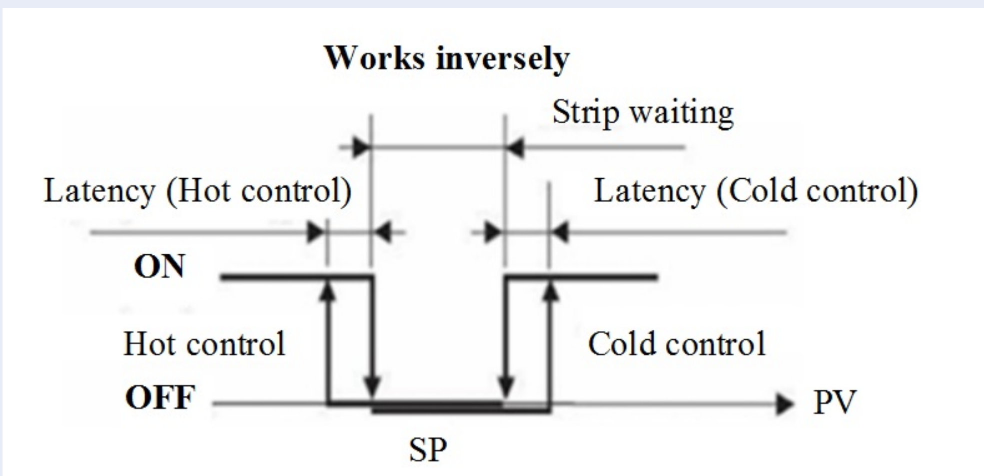

Figure 5: Working principle of ON/OFF mode

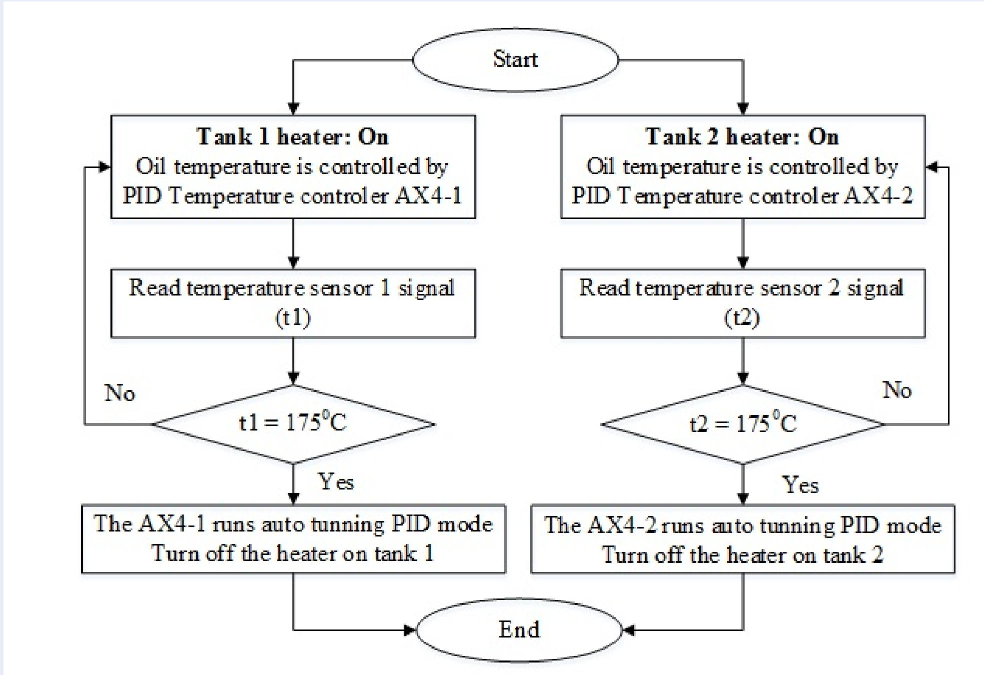

Figure 6: Flowchart of temperature control

A. Choosing temperature controller

According to the paper of Lynn J. Hubbard and Brian E. Farkas the oil temperature effects a lot on the convective heat transfer during the immersion frying[9]. That is why the oil heat control is a problem need to be concerned carefully. However, because of the developed by the control technology the oil temperature now can be controlled precisely by PID control method. If the oil temperature does not control to meet the require temperature, it will effect to the quality of the tempura shrimps.

Based on the requirement above, the temperature controller Hanyoung Nux AX4 is chosen.

B. Heat resistance controller

This heating resistors system is responsible for providing heat for the entire volume of oil in the 1st frying module. The heat will be provided through 12 resistors with the capacity of each one is 1kW. The total capacity of 12kW. Maintaining the desired temperature is managed by the temperature controller, the controller will update the actual temperature in the oil tank through the K thermocouple probe (Pt100). The desired oil temperature is around 1750C, the controller will proceed to manage the operation of the SSR to open or close the electricity to the resistors. As in Figure 7, these 12 resistors will be divided into 4 sections; each section includes 3 resistors which are connected by a triangle method. Each section will be supplied with a separate 3-phase power supply for different purposes such as separating the operation plan of each section or 1 section can be used for the deduction when the other section fails to meet the production plan. The electrical system of the oil heating resistors consists of 2 parts: (1) The power part includes total CB, 4 CB sections thermistor, radiator fan, 12 thermistors, indicator light; (2) The control part includes an emergency button, On / Off switch, AX4 temperature controller, SSR DD, SSR DA.

After activating the main CB, the electricity has not yet been supplied to the thermistor, as each heating resistor section is further managed by separate CBs.

After pushing the power supply switch to the control circuit, the heat sink fan will be turned on immediately to perform heat dissipation. At the same time, the indicator light and the AX4 controller are also powered, at this time the controller will read the sensor signal and perform its function of opening and closing the SSR control contact at pins 1 and 2. At this time, of the heating CB is already turned on, the SSR DD will be activated to supply for 12 SSR DA to conduct electricity into the heating resistors.

Powder solution spraying controller

From design and calculate mechanic of the injection barrel there are some parameters that needed to design the control system for injection powder solution.

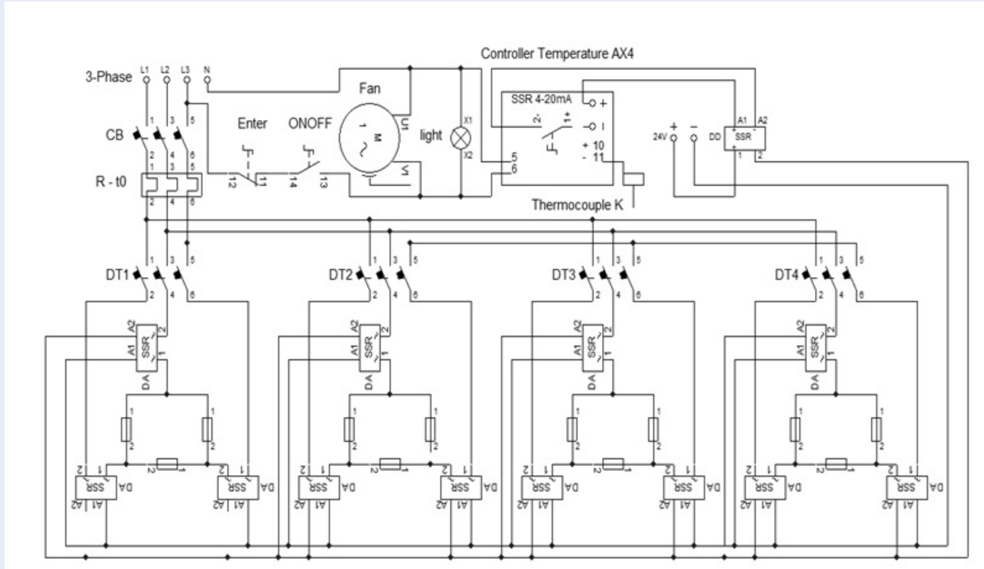

Figure 7: Electric diagram of control heat resistance

The control diagram of the powder solution is presented in Figure 8 below. Maximum time injects the powder solution for shrimp: t = 0.5s. Air pressures need to apply to the barrel is: p = 0.04kg/cm^3. The liquid level sensor chosen for this system is Hanyoung Nux FS-3A. The proximity sensor using to active the spraying procedure is Omron E3Z – T61. The control circuit of the powder solution injection module is introduced inFigure 9.

C. Electric and control principle

The position sensor will return signal to the PLC whenever the fried–mold reaches the inject position and the solenoid valve is ON in enough period of time to cover shrimp with powder solution. This operation time to inject the powder solution depends on the size of shrimps. The powder solution injection system is placed above the mold conveyor (module 1) to provide an amount of the tempura powder solution to the top of the shrimp right at the oil surface to create a fluffy layer on the outside. The powder solution injection electrical system consists of 2 parts: (1) The system checks the powder level and alarms to the workers when the powder solution level is nearly empty; (2) The system receives the signal of the proximity sensor to note that the shrimp molds have been located in the operating position. Then, it will activate the solenoid valve to let the compressed air cylinder to open the powder path to spray down to liquid to the shrimp molds.

The diagram is divided into 2 parts: the dynamic part and the control part: (1) Motive part includes CB total, contactor; (2) Control part includes: Start button, Stop button, Timer, Proximity sensor, 2 solenoid coil, level sensor, level sensor controller, buzzer. After wiping CB to supply power to the powder injection system, electricity has not been supplied to the system when the contactor's 2 main KM contacts have not been affected. After pressing the Start button, the new system is supplied with power through a KM self-holding contact that continuously supplies power to

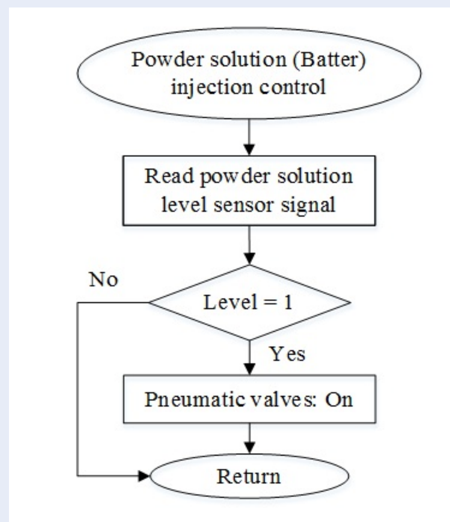

Figure 8: Flowchart of powder solution injection control process

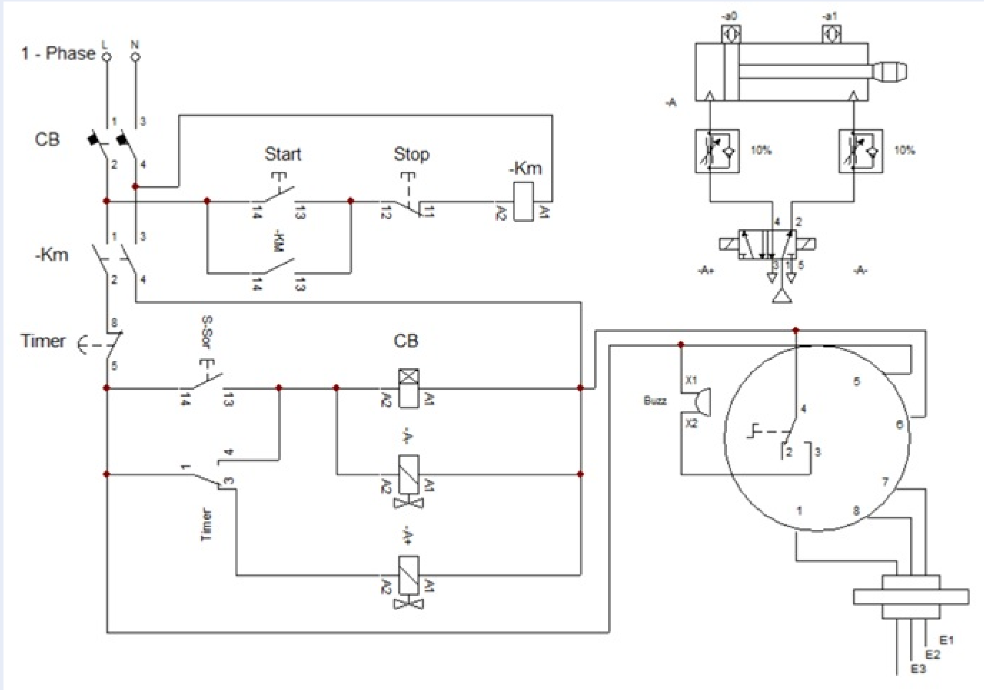

Figure 9: Control diagram of powder solution injection in module 1

the KM coil after the Start button is released. At this moment, an energized A + coil hits the compressed air cylinder that closes the powdered sugar and waits for the proximity sensor signal to be activated.

OIL FILTER MODULE

Function: Filter the cooked oil in real-time and create a dynamic oil flow to take fried oil and fried crumbs to oil filter, then take filtered oil back to system.

The structure of the oil filter includes oil filter part, pump and tubes are introduced in Figure 10.

During the frying process, oil can be mixed with fried crumb came from powder solution in powder solution injection process. When fried oil flow to the back of module 1 it will be sucked away by suction tube and flow into oil filter module where fried oil is filtered and the pumped back to frying box through the thrust tube and complete the filter cycle. The oil filter chosen for this system is LF30-JY-5/250~350L.

Pump and tubes

On the oil surface, there're two holes: suction and thrust on two sides which are vertically opposite each other. Then the oil will go in a closed loop from the fryer, the suction tube, the filter, the thrust tube and back into the fryer. At the same time, the pressure from the pump will also create a flow in the fryer, moving the crumbs towards the suction tube, bringing in and being filtered out at the oil filter afterwards. The tube diameter and the flow rate of the machine are dependent on the filter speed of the oil filter, so that the frying oil always meets the standard of food safety and there isn't broken crumbs that burn in the fryer. In our system, the tube diameter is chosen as 34mm, and external gear pump with high performance is AZPB.

THE CONTROLLER DESIGN FOR MODULE 2

The main function of module 2 is deep fry the shrimps. So, it has the function to choose 8 different modes of conveyor speed to match with the different types of shrimps with respect to different frying times. The oil filter module and temperature control module are similar as module1. In Figure 12, similar to the motor control system of module 1, two 3 phase AC motors drive the conveyor to evenly fry the shrimp (called fry conveyor) and the conveyor that passes the shrimp to module 3 (called pass conveyor). These two motors are also controlled by LS-IG5A inverters. It will be able to set the suitable speed with respect to different sizes of shrimp because each size requires a different frying time. The potentiometers are used to change the velocity of the motor manually. While all

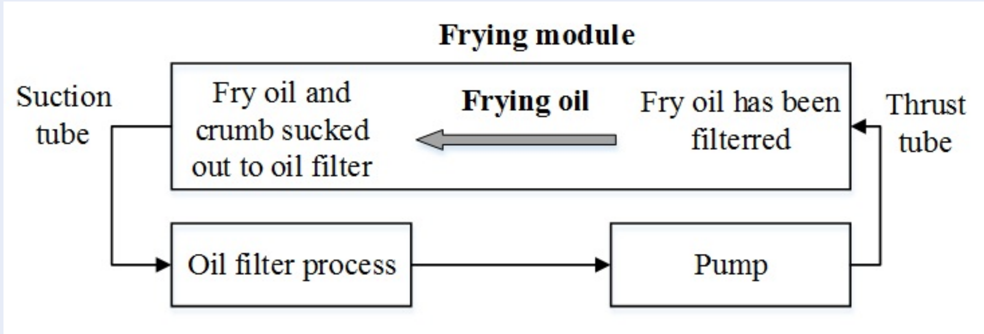

Figure 10: Block diagram of oil filter module

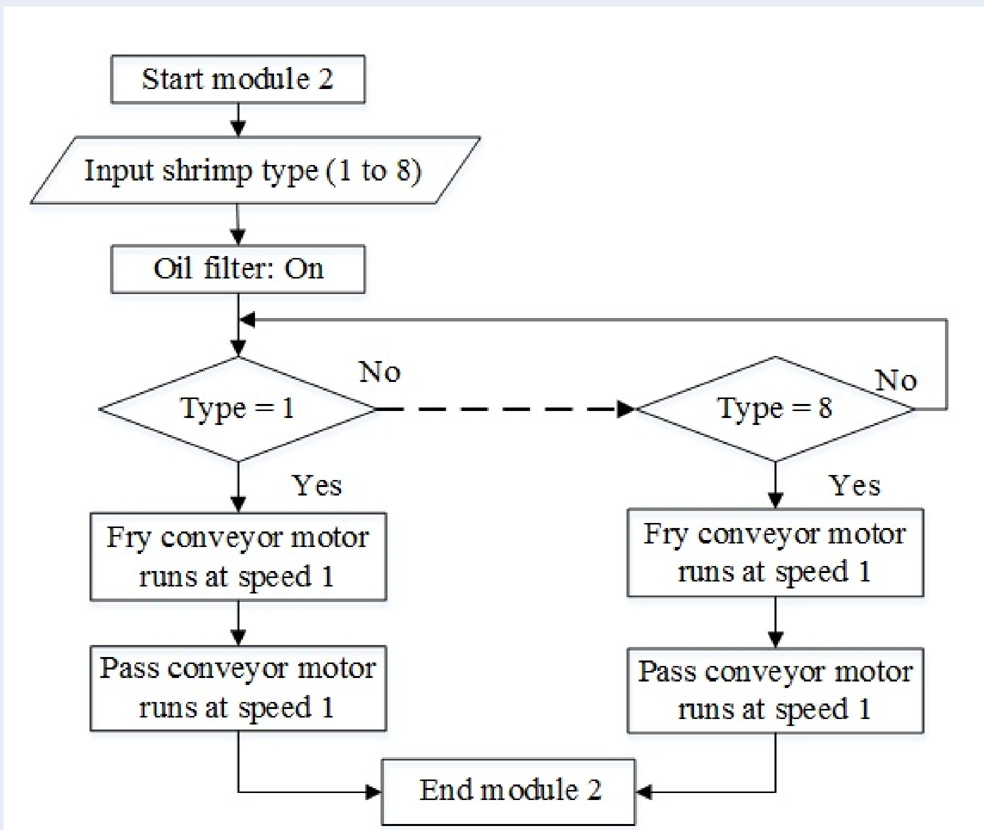

Figure 11: Flowchart of second frying module control system

sizes of shrimp move through the first frying module at a constant speed, in the second frying module, the conveyor speed must be changed according to each shrimp size. The control diagram of the motor speed variation with respect to the different size of the shrimps are described inFigure 11.

As different types of shrimps, it will be different speed of motors in order not to overcook or undercook the shrimps. With 8 types of shrimp, there are 8 modes of motor speed which can be adjusted through the inverter as introduced in Figure 11.

Similar to the operation of the motor control at the first frying module. The control circuit of the second frying module has the same operation principle of module 1 and is introduced in Figure 12. After the CB is activated, press the start button and the inverter enable switch to activate the motors, thence adjusting the inverter parameters to change the speed of motors. The circuit will stop working when switch the CB off, press the Stop button or the Emergency button.

THE CONTROLLER DESIGN FOR MODULE 3

The module 3 is called oil draining module. This module has the function to extract the oil inside the finished tempura shrimps to improve the quality of the tempura shrimps. According to Timothy G. Kemper, the residual oil inside fat and oil products has been noticed and people have many ways to extract oil out, from hand press extraction, hydraulic press using a screw press to extract the oil [10]. But none of them is suitable for shrimp situation, which is easy to deform and broke the batter cover outside the shrimp and loss of aesthetics. Because of that, the air pressure is introduced as one of the most effective candidates, which can be created by a fan with suitable power and the heat from the heater resistor that is module 3: the oil draining module. The control circuit of this module is described in Figure 13.

Module 3 plays the role of driving shrimp through a high-capacity hot air blower system to reduce fried oil in shrimp after frying. The system includes a stainless steel net conveyor to bring the shrimp from the 2nd module through the blower system to get the oil draining process. For the oil draining system for tempura shrimp, the specialized industrial drying fan for food D090FT 9KW is proposed.

Electric – Control system includes 2 parts: (1) Electric: conveyor motor, drying fan system, with CBs, contactors, inverters; (2) Control: Conveyor motor speed control, drying fan motor speed control, and temperature control in drying fan system. Using similar components and principles presented in 1st and 2nd module.

After wiping the CB, the power is still not supplied, after pressing the Start button, electricity is maintained in the coil, the fan blows with high capacity and closes the main contacts which supply power to the inverter. At this point, switch the On/Off switch to enable the motor and adjust the drive to achieve the desired speed. The system stops working when cutting off CB, press the stop button or press the Emergency button.

RESULTS AND DISCUSSION

In this research topic, the controller design of the semi-automation shrimp tempura frying production line are introduced. This production line is designed which is totally based on the manual frying process in the industries and specialized in the shrimp tempura production factory. Because this production system is used in the food industry, therefore the whole production line is made of stainless steel. The entire system is designed according to the modulation concept. This allows each module of the system to function as an independent machine. However, in order to make the production line meet the requirement about the tempura shrimp frying standard in the factory, these three main modules have the good cooperation together both in the mechanical and also in the control process. In general, in this production line, the control technology being proposed is based on the industry standard. The main parameters of the whole system need to be controlled are the conveyor speed, the temperature of the frying oil tanks, the pressure inside the power solution tank, the amount of the powder solution to be injected on the shrimps, the temperature of the oil draining system and also the speed of the cooling fan of the oil draining system. The conveyor speed is controlled by an inverter. The temperature of each module is monitored and controlled by the industrial devices that can support the PID auto-tuning process for the heat problem.

Because of the different sizes of the shrimps, the speed of the conveyors and other controlled parameters are also different. For example, the big size shrimps need much amount of powder solution to cover and also take longer time to be cooked and vice versal. All controlled parameters of this tempura shrimp frying production line are chosen automatically according to the size of the shrimp. The shrimps size is input to the system to be the initial data to allow the whole system to operate perfectly in terms of the size of the shrimp.

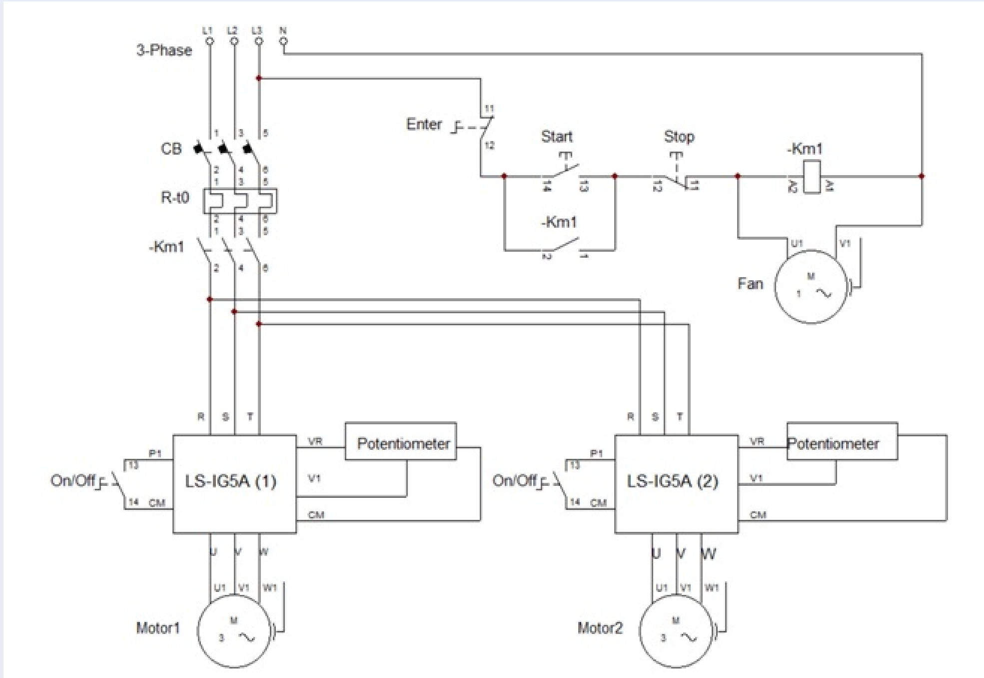

Figure 12: Circuit diagram of the inverter controlling two 3-phase motors of the second frying module.

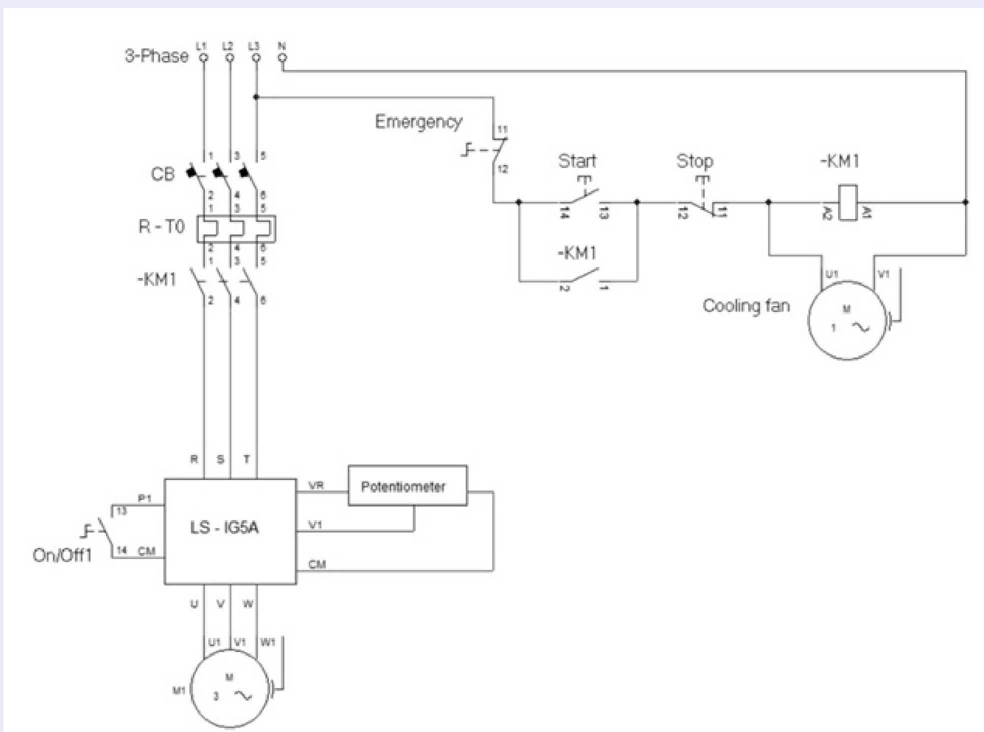

Figure 13: Control circuit diagram of module 3

Despite each module in the whole system can operate independently, but they are all communicated and synchronized together by the main PLC of the whole system. At some primary experimental results, the operation of the whole shrimp tempura frying production line can work well with the desired results to meet the industry requirements. At present, the design of the mechanical part and also the design of the controller in this whole production line still have been researching to get better results and much more optimization about the power consumption issue.

CONCLUSION

This paper has proposed the control system for the semi-automation shrimp Tempura frying production line. For the oil issue, the temperature of oil can be determined and controlled through the Hanyoung Nux AX4 module, also the oil will be filtered in order not to be heated so much which will cause some health problem. With three main modules of the whole process, the shrimps will be formed (fried first time), completely fried with standard quality (fried second time) and extracted most oil left inside the shrimp (oil drain). The controller for each module is also designed to help each module can operate independently and well-cooperated together to help the system operate to meet the requirement of the factory. For the batter problem, now through the injection module the shrimp will be covered in the predefined amount of batter which will cause loss of aesthetics for not enough batter or burnt the outside but not enough ripe inside for too much batter. For the motors control problem, with the different types of shrimp, the different speeds of the motors are applied respectively, which is directly affected on the time shrimp is fried. The inverter solved this problem which can control the speed of the motor lead to the speed of the conveyor and the time shrimp is fried. All the control modules can control and updated data frequently by the PLC control act like the main monitor to connect and control all modules and make sure the whole system operates smoothly and safety. For the extracted oil inside shrimp after fried stage, with the drying fan system and the heat resistors the shrimp now able to avoid the oil degeneration phenomenon caused by preserving the tempura shrimps for a long time in the frozen condition to prepare for exporting.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

AUTHORS' CONTRIBUTIONS

Tuong Quan Vo is the principal author and the corresponding author. He is in charge of the main ideas to build up this system from the beginning. He is also responsible for the sketch design of the mechanical, electrical – electronics and the controllers for this research topic. He writes the first draft, evaluate and correct the technical issues and English of this manuscript. Besides, he instructs all the members to complete their task of this research. Trung Chanh Vo and Tran Thanh Cong Vu are responsible for completing the design of the mechanical system of module 1 and module 2, 3 respectively. Tuan Quan Vuong contributes to the complete controller design of module 1. Quang Minh Phan is in charge of the complete controller design of module 2. Finally, Tan Dat Nguyen and Quang Long Le contribute to the final design of the module 3 controller. All the authors have read and agreed to the published version of this manuscript.

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Bài nghiên cứu

Thiết kế bộ điều khiển cho dây chuyền chiên tôm Tempura bán tự động

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TÓM TẮT
Ngày nay, việc ứng dụng các hệ thống tự động hóa đã được phát triển rất nhiều trong các ngành công nghiệp khác nhau. Một trong những ngành công nghiệp mũi nhọn cần được quan tâm và tập trung phát triển các công nghệ tự động hóa để giảm nhân công và tăng năng suất sản xuất là ngành công nghiệp thủy hải sản. Ngành công nghiệp thủy hải sản này cần rất nhiều nhân công và phần lớn các công việc thực hiện đều là thủ công. Do đó, có rất nhiều các nghiên cứu cần được thực hiện trong lĩnh vực này để giúp cho sự phát triển của ngành công nghiệp này trong xu thế thời đại 4.0 hiện nay. Dây chuyền chiên tôm Tempura là một hệ thống sản xuất tôm chiên theo kiểu Tempura với năng suất cao. Công nhân chỉ thực hiện công việc bỏ tôm đã được chuẩn bị sẵn vào các khuôn chiên nối tiếp nhau và hệ thống sẽ tự động thực hiện các quy trình còn lại để tạo ra tôm chiên Tempura thành phẩm. Quy trình chiên tôm Tempura bao gồm các bước sau: (1) Định hình tôm và phủ tôm với dung dịch bột chiên Tempura thông qua hệ thống phun bột tự động; (2) Chiên hoàn thiện tôm; (3) Hệ thống làm ráo dầu sẽ giúp làm rút bớt dầu chiên đọng bên trong tôm và bột tempura bao xung quanh tôm. Sau đó, tôm chiên Tempura thành phẩm sẽ được đông lạnh để bảo quản. Dây chuyền chiên tôm Tempura bán tự động được thiết kế bao gồm 03 module chính sau: Module 1: Module định hình tôm (Giai đoạn chiên tôm lần 1) và phun dung dịch bột Tempura lên tôm; Module 2: Module chiên hoàn thiện (Giai đoạn chiên tôm lần 2); Module 3: Module làm ráo bớt dầu trong tôm sau khi chiên. Bài báo này giới thiệu về hệ thống điều khiển được thiết kế cho từng module chức năng của dây chuyền và hệ thống điều khiển của toàn bộ dây chuyền chiên tôm Tempura bán tự động.
Một số kỹ thuật điều khiển được sử dụng trong hệ thống như: điều khiển On/Off, giải thuật PID, được nghiên cứu để sử dụng cho toàn bộ hệ thống. Các thông số được điều khiển như: vận tốc dài của các băng tải xích (làm bằng thép không rỉ), nhiệt độ bồn chiên tôm, định lượng dung dịch bột Tempura phun lên tôm, vận tốc dài của băng tải làm ráo dầu trong tôm, nhiệt độ và lưu lượng gió của hệ thống làm ráo dầu trong tôm Tempura.

Từ khoá: Hệ thống điều khiển, bán tự động, Tempura, tôm chiên, dung dịch bột, hệ thống phun, điều khiển nhiệt độ, điều khiển tốc độ

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