Fluid Mixing Process Based on Programmable Logic Controller as Training Kit for Electrical Engineering Education Students

Puput Wanarti Rusimamto[1*], Munoto[1], Muchlas Samani[2], I G.P. Asto Buditjahjanto[1], Ekohariadi[3], Luthfiyah Nurlaela[4], Mohammad Nuh[5], Endryansyah[1],

[1]Universitas Negeri Surabaya, Electrical Engineering, Surabaya, 60231, INDONESIA

[2]Universitas Negeri Surabaya, Mechanical Engineering, Surabaya, 60231, INDONESIA

[3]Universitas Negeri Surabaya, Informatics Engineering, Surabaya, 60231, INDONESIA

[4]Universitas Negeri Surabaya, Vocational Education, Surabaya, 60231, INDONESIA

[5]Institut Teknologi Sepuluh Nopember, Electrical Engineering, Surabaya, 60111, INDONESIA

*Corresponding Author

Abstract: The Department of Electrical Engineering, Universitas Negeri Surabaya (Unesa) is developing a laboratory, including a control system laboratory. The control system engineering teaching team prepares themselves by making a PLC training kit to accompany the existing modules. With the aim that students know and understand the application of control systems in industry. This can foster student learning motivation in attending lectures and greatly support student competence before entering the workplace. The study used is development research by producing a product prototype in the form of a fluid mixing process training kit. The steps taken are designing, making tools, integrating software to hardware and validating the tools. The result of the research is that the fluid mixing process training kit has worked according to the instructions given and is suitable for use as a learning medium.

Keywords: Fluid mixing process, PLC, training kit, electrical engineering education students

1. Introduction

Entering the 21st century, the national education system encounter very complex challenges in preparing the quality of human resources who can compete in the global era. The right effort to prepare quality human resources and function as tools for building high quality human resources is education. Meanwhile, every company and every professional demands and requires the four most sustainable competencies which are referred to as the four Cs or 4C's and must be prepared for students [1]. The 4C's are critical thinking, communication, collaboration, and creativity and innovation. This was also conveyed by the National Education Association (NEA) based in the USA through the educators who are members of it. In the 21st century, the focus of the task of teachers is much stronger is on these four competencies [2].

With the demands of the 21st century for teachers who must prepare students to have 4 competencies, then the Department of Electrical Engineering Education (PTE) of the Universitas Negeri Surabaya must equip prospective teachers or professionals to compensate for the changes that are happening quickly and become the front line in these

changes. One of the knowledge and skills that a PTE study program must have is the PLC (Programmable Logic Controller) programming competency.

PLC programming competence is needed in the industry. PLC has been successfully applied to every segment of the industry, including steel mills, paper mills, food processing plants, chemical plants and power plants. PLCs perform a variety of regulatory tasks, from repetitive ON/OFF settings from simple machines to sophisticated manufacturing and process settings. Automation systems in industry include operations such as processing, assembling, inspection and material handling, in many cases completing more than one of these operations in the same system. It is called automatic because it performs operations with a lower level of human participation compared to manual processes. In some highly automated systems, there is almost no human participation [3].

Kiangala (2019) has presented that the latest manufacturing process trends, such as Industry 4.0 (I.4.0), are trying to replace existing manual systems with processes that can be reset and controlled by themselves to improve the overall production system. The PLC used is the Siemens S7-1200 which communicates via Ethernet TCP/IP with the ZENON SCADA Human Machine Interface (HMI) to closely track production, reduce manual control, and efficiently monitor the bottling process of small beverage factories by applying the basic concept of I.4.0 such as decentralization and real time data analysis [4]. Meanwhile Rowe (2020) has succeeded in creating a framework to guide PLC practicum in Undergraduate Engineering Education at the University of Colorado Boulder. As a result, alumni praised the incorporation of classroom and practical assignments into "PLC programming activities", indicating a statistically significant reported impact [5]. Bassily (2007) also presents an educational mechatronics laboratory that encourages multi-disciplinary direct engineering discoveries. The three experiments made were a kit to program and operate a PLC, a traditional conveyor system, and a distributed servo motor-based conveyor [6].

The learning outcomes of students who took PLC courses in 2018 with the greatest score were B+ as much as 24.3% of 37 students. In 2019, students who took PLC courses with the highest scores were A- only 1 student out of 51 students and B+ scores of 43%. Such value distribution is considered difficult by students when learning PLC programming. According to the results of initial observations made, only a few students were active in participating in PLC learning. Students also think that PLC learning is very difficult. The obstacles faced by students in this course are in terms of using programming logic and basic concepts of programming languages. With the low student learning outcomes of PLC, because of the low ability of students in PLC programming.

To respond to the unachieved achievement of PLC learning, one effort that can be done is to implement a media kit as a tool in the student learning process. The optimal application of media kits allows PLC learning to occur which gives students the opportunity to gain learning experiences according to the expected competencies. This is in line with the research of Coskun (2009) and Yilmas (2011) which concluded the benefits of the PLC training kit media for learning. In addition, it allows students to develop their potential through high learning activities in a pleasant atmosphere. As well as obtaining knowledge using experience, cognitive structures, and beliefs [7][8].

The results of the description above can be underlined that PTE students whose graduates produce teaching and/or professional staff must have the skills needed to become teachers or professionals in the industry. Problems arise in the learning process of PLC, so research is carried out on the application of PLC as a training kit to improve the PLC programming skills of PTE students. The PLC application is making a fluid mixing process prototype.

2. Methodology

The procedure for making a PLC-based fluid mixing process prototype uses a development model, which results in a product in the form of a PLC training kit that accompanies modules and instruments to measure critical thinking skills in PLC programming competencies of PTE Unesa students [9].

Plomp (2007) recommends that the development model refers to the Research and Development (R & D) cycle model, which includes the following activities. (1) preliminary investigation, (2) design, (3) realization/construction, (4) test, evaluation and revision, and (5) implementation [10]. Meanwhile, according to Borg & Gall in Sugiyono (2010), there are 10 (ten) stages of using research and development methods, namely (1) potential and problem stages, (2) data collection stage, (3) product design stage, (4) the design validation stage, (5) the design revision stage, (6) the product trial stage, (7) the product revision stage, (8) the use trial stage, (9) the product revision stage, (10) the mass production stage. But in this study, 7 (seven) stages were carried out because the PLC training kit media was not mass produced. The steps taken are potential and problems, data collection, product design, design validation, design revision, product testing, analysis and reporting [11].

2.1. PLC Training Kit

PLC is a control device that can be programmed to control the operation of machines or processes in industry. It can also be said as an automatic control system that is currently widely used in industry. Because almost all industries, both small, medium and large industries use PLC, students are required to master competencies in the field of this control system. According to William Bolton (2006), PLC is a special form of microprocessor-based controller that utilizes memory and can be programmed to store instructions and implement functions such as logic, timing, counting, and arithmetic to control machines and processes[12]. The types of PLCs used in the industrial automation world include

Omron, Schneider, Mitsubishi, Festo, Siemens and many more on the market. To run a PLC, a software program is required. PLC used for this research is PLC Omron type CP1E with the software used is CX-Programmer, CX-Designer and CX-Simulator. In this study, the kit to be developed is a PLC kit for the fluid mixing process control system practicum.

2.2. PLC Training Kit Design

The fluid mixing process is suitable for the beverage industry. The beverage industry in the process requires mixing of ingredients before finally becoming a drink that is ready to drink. In this study, a mixture of 2 fluids was used, namely water and syrup with the design shown in Fig. 1.
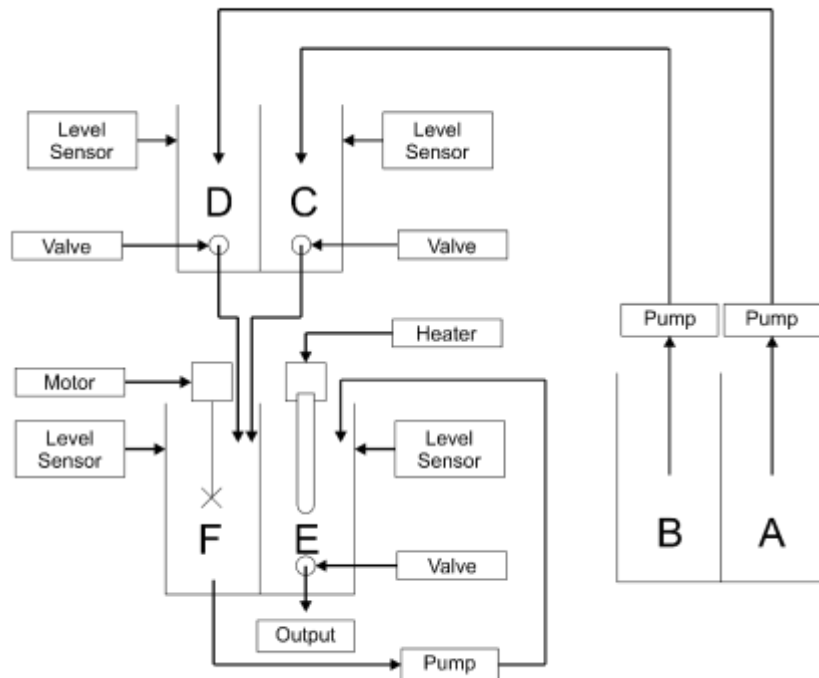

Fig. 1 - PLC based fluid mixing process design

The system is designed to have six liquid storage tanks. Starting from tank A which contains water and tank B which contains syrup. Then the water and syrup are channeled and pumped by water pumps A and B towards tanks D and C until tanks D and E are full which is regulated by the water level sensor.

After the water and syrup have filled tanks D and C, the water level sensor will work to turn off the water pump A and B, and turn on the sensors on valves D and C. Then fill the mixing tank F to the full which has been set with the water level sensor, after full the sensor works and turns on the stirring motor for a predetermined time.

After the motor has finished stirring and the mixed beverage liquid will be pumped by pump F to the heating tank E. The filling continues until all the liquid enters then the water level sensor will work to turn on the heater. The heater will work with a temperature sensor, then the heater will turn off then valve E will open to carry out the next process.

2.3. Feasibility of the PLC Training Kit

According to Nieven (2010) the feasibility of learning media is an indicator of whether or not a learning media can be used in the teaching and learning process. There are three aspects that need to be considered in assessing product quality from development research including validity, effectiveness, and practicality [10]. In this study, to determine the feasibility of the training kit only through the validity of instructional media experts and regulatory system engineering experts. Validity is a training kit assessment process for learning. Suggestions from experts for revising learning media are needed as an assessment. Validity is divided into three, namely content validity, construct validity, and criterion-related validity [13]. Content validity relates to the ability of an instrument to measure the content (concept) that must be measured. The content of a concept or variable to be measured can be revealed by a measuring instrument. Validity based on criteria is the validation of an instrument by comparing it with other valid and reliable measurements by correlating it. The instrument is said to have criterion validity, if the correlation is significant. Construct validity is the framework of a concept, which relates to the ability of a measuring instrument to measure the meaning of a concept it is measuring.

The aspects and indicators used in the validity of the PLC training kit are as follows. 1) The suitability of the training kit with learning outcomes which includes a) the training kit is in accordance with the teaching material presented, b) the use of a training kit helps understanding the material presented. 2) The appearance and quality of the training kit which includes a) the design of the training kit, b) the suitability of the size of the training kit box with the circuit, c) the layout of the circuit in the training kit, d) clarity of the drawing/circuit scheme on the training kit (description of component symbols and names parts of each circuit), e) the writings on the training kit are clearly legible, f) the accuracy of the wiring-point layout, g) the length of the connector cable as needed, h) the ease of connecting the connectors on the training kit, i) easy access to each circuit, j) the performance of the training kit and k) the ease of operation/use of the training kit. 3) Suitability of the training kit with the module which includes a) suitability of the training kit with module material and b) practicum activities with the training kit according to what is contained in the module.

3.   Results and Discussion

After going through the design stage, the next step is to make a PLC-based fluid mixing process prototype. The PLC-based fluid mixing process prototype as a training kit is made from lightweight materials and is easily available in the market. Made with due regard to visual principles, namely visible, interesting, simple, useful, accurate, legitimate, structured [14]. The PLC training kit is made in a square box measuring 55 cm x 55 cm x 10 cm and the layout of the components is neatly in the box as shown in Figure 2. The design for making a PLC training kit is as follows. The type of PLC used is the Omron CP1E, with a 220 V AC voltage source, 6 plus 1 COM input and 4 plus 3 COM output, 4 12V Relays, 95 plug terminals, 30 connecting cables. The power supply consists of 1 1A transformer, AC 220V input voltage, 3V/4.5V/6V/9V/12V DC output voltage. PLC input application is a mixing process made separately from a box consisting of 2 tanks with a capacity of 1 liter each, 3 motor pumps with 9 V DC voltage, 1 mixer motor with 6 V DC voltage, 4 water level sensors with DC voltage 24 V, 1 heater with 220 V AC voltage, 2 relays with 9 V DC voltage, 3 water valves with 12 V DC voltage and 3 8pin terminals. All components are neatly arranged and easy to use. The components required for the manufacture of a training kit are shown in Table 1 below.

Table 1 - Components for making a training kit

No	Material Name	Quantity	Specifications
1	Water Pump	3 pieces	9V DC
2	Valve	3 pieces	12V DC
3	Mixer	1 pieces	6V DC
4	Level Sensor (LS)	4 pieces	24V DC
5	Heater	1 pieces	220V AC
6	Relay	2 pieces	9V DC

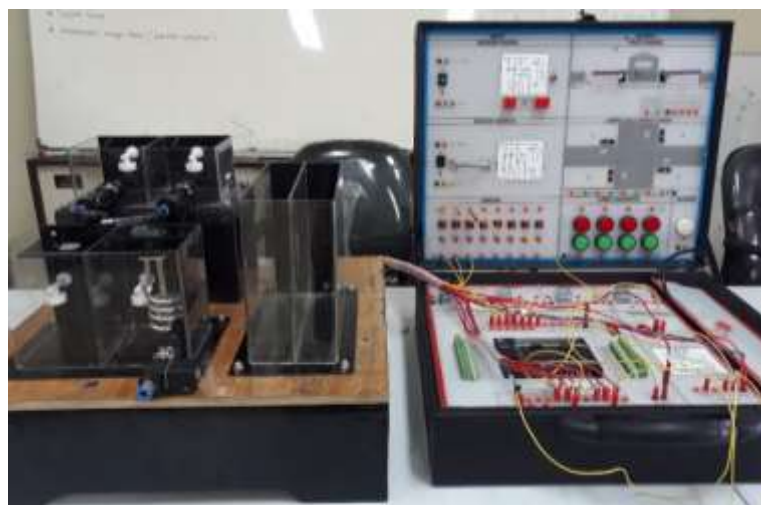The PLC-based fluid mixing process training kit is shown in Fig. 2 below.

Fig. 2 - Fluid mixing process training kit

The PLC used is PLC made by Omron type CP1E. Because this type of PLC is widely used in industry by adjusting industrial needs. By using the CP1E PLC, students or students will be familiar with the PLC, so that when they are involved in the industry they are familiar and easier to adapt. The PLC-based fluid mixing system flowchart is shown in Fig. 3 below.
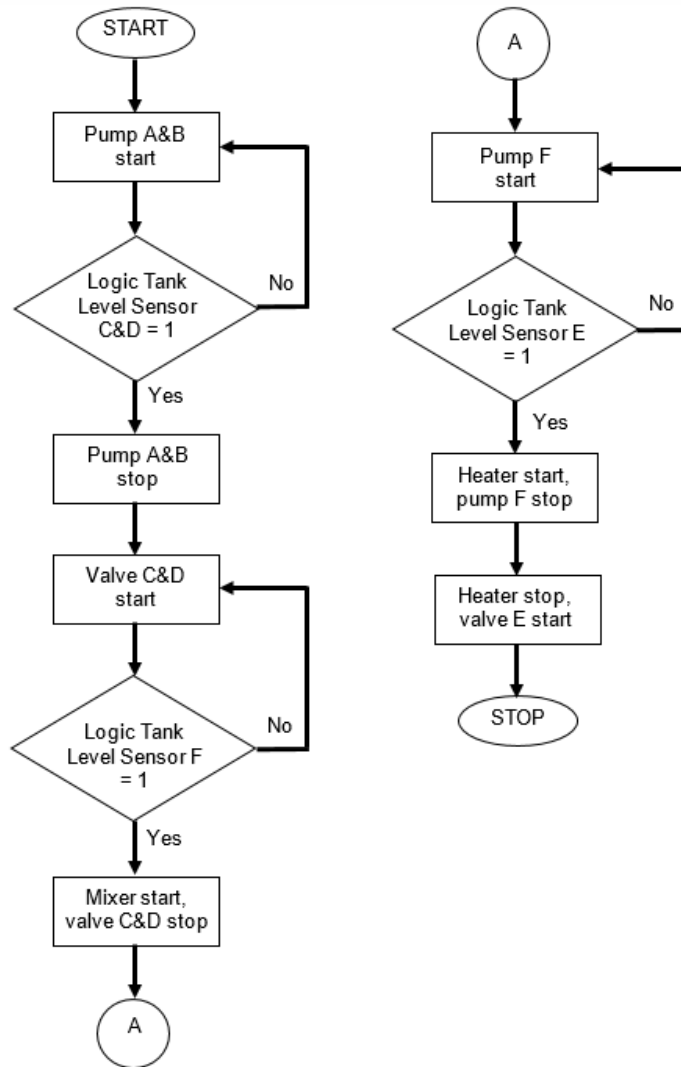
Fig. 3 - Fluid mixing system flowchart

After the kit is complete, the next step is programming through CX-Programmer. Then the software to hardware integration process is carried out through uploading the program to the PLC. The trials results are shown in Fig. 4 below.
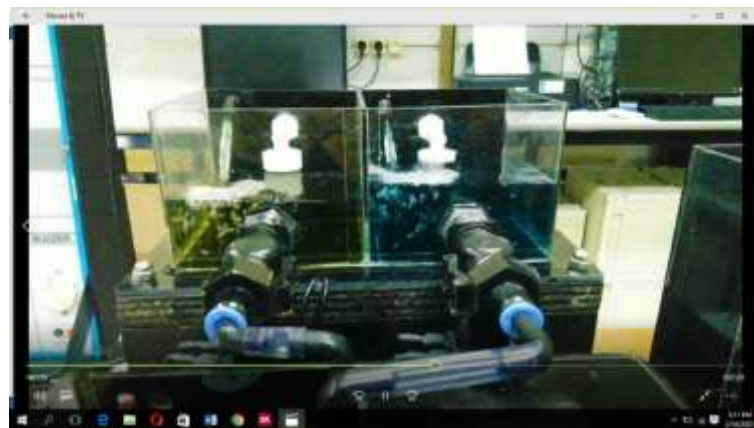
Fig. 4 - Trials PLC training kit

From Fig. 3 it is described as follows. The program starts, then pumps A and B turn on and the tank filling process occurs. When the level sensors C and D detect the water level limit, pumps A and B stop. Then valves C and D open to empty the tank. When the level sensor F detects the water level limit, valves C and D close. Then the mixer runs. When the mixer stops, pump F starts. When the level sensor E detects the water level limit, the pump F stops. Heater will run.

If the heater has gone out, then valve E turns on to empty the water in the heater tank to the next process. The component condition when the program is run is shown in Table 2 below.

Table 2 - Component condition when the program is run

Component/	STEP								
Step	1	2	3	4	5	6	7	8	9
Pump A	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Pump B	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Pump F	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF
Valve C	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
Valve D	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
Valve E	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
Mixer	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
Heater	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
LS C	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
LS D	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
LS F	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
LS E	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF

After the training kit is complete and the program can be run according to the instructions, the next step is the validity of the training kit. To find out the validity of the training kit produced, it must be validated by a validator who is an expert in their field. The validator consists of 3 (three) experts, the first, an expert in the field of education and evaluation, the second expert is education and learning media and the third expert is in the field of control system engineering and PLC.

From the results of the validator's assessment, the rating results of each indicator/aspect being assessed will be calculated. Then the rating results will be categorized according to the assessment criteria using a Likert scale developed by Rensis Likert (1932). Likert scale is used to measure a person's perception, attitude or opinion regarding an event or social phenomenon. This scale is a psychometric scale that is usually applied in questionnaires and is most often used for research in the form of surveys, including in descriptive survey research. Likert scale calculation uses the following formulas [15].

Formula: $T \times Pn$ (1)
Information:
T = Total number of respondents who voted
Pn = Choice of Likert score

In order to obtain interpretation results, first the highest score (X) and lowest score (Y) must be known for the assessment item with the following formula:
Y = highest Likert score x number of respondents
X = lowest Likert score x number of respondents
The respondent's interpretation of the assessment is the value generated using the% Index formula.

$Index\% formula = Total Score/Y \times 100$ (2)

To find out the assessment by the method of finding the percent score interval (I) with the following formula.

$I = 100/Total Score (Likert)$ (3)

This is the interval from the lowest 0% to the highest 100%.

The results of the training kit validation were analyzed using a Likert scale which is shown in Table 3 below.

Table 3 - The results of the training kit validation and calculations using a Likert scale

No	Aspect	Indicator	Number of validators who judge				TxPn	Index %	Interpre-tation
			1	2	3	4			
1	Suitability of the training kit with learning outcomes	a. The training kit is in accordance with the teaching material presented				3	12	100.00	Very good
		b. The use of a training kit helps understanding the material presented				3	12	100.00	Very good
2	Appearance and quality of the training kit	a. Training kit design			1	2	11	91.67	Very good
		b. Match the size of the training kit box with the circuit			1	2	11	91.67	Very good
		c. The circuit layout in the training kit			1	2	11	91.67	Very good
		d. The clarity of the drawing/circuit scheme in the training kit (description of component symbols and names of parts of each circuit)			1	2	11	91.67	Very good
		e. The writings on the training kit are clearly legible			1	2	11	91.67	Very good
		f. Wiring-point layout accuracy			1	2	11	91.67	Very good
		g. The length of the connector cable is as needed				3	12	100.00	Very good
		h. Ease of attaching connectors to the training kit				3	12	100.00	Very good
		i. Ease of access on each circuit				3	12	100.00	Very good
		j. Performance training kit			2	1	10	83.33	Very good
		k. Ease of operation/use of the training kit			1	2	11	91.67	Very good
3	Suitability of the training kit with the module	a. The suitability of the training kit with the module material			1	2	11	91.67	Very good
		b. Practicum activities with a training kit according to the one in the module				3	12	100.00	Very good

From the results shown in Table 3, it appears that the lowest index value is in the training kit performance indicator. This can be explained as follows. When the training kit is run, the process can run properly according to the instructions. The problem with the mechanics is that the tank has fluid remaining due to the inadequate placement of the valve. The appearance and quality of the training kit in general still need to be improved, especially in its design. The design is too big so it is difficult to move around. In general, it is good with an average index result of 94.44%, which means that the PLC-based fluid mixing process training kit has a very good Likert index interpretation. So that this PLC training kit is suitable for use in PLC learning. In line with Gavali (2016) who said that laboratory demonstration projects provide opportunities for students to apply the knowledge gained in lectures to real engineering problems. Assessment shows that students have a better response to technology-based practicum activities [16]. In line with Patel's (2014) research which has successfully implemented a process loop that can be used in a bottle washer with efficient control using a PLC. PLC is the best solution for better results [17]. Likewise, Sukir (2019) has successfully developed a PLC-based Electrical Machine Trainer Kit. The PLC-based Electrical Machinery Trainer kit showed satisfactory performance, indicated by all the job descriptions to function properly according to plan [18].

4. Conclusion

From the results of the discussion, it can be concluded that it has succeeded in making a fluid mixing process prototype that can be used as a training kit to improve PTE students' PLC programming skills. The fluid mixing process training kit has worked according to the instructions given and is suitable for use as a learning medium with a Likert index value of 94.44%.

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