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Automation system modeling for small biodiesel production plant

A Dissertation
Presented to
The Engineering Institute of Technology

by

Otto Jesus Ribeiro

Student Number

1654442

In Partial Fulfillment
of the Requirements for the Degree
Master of Engineering in
Industrial Automation

Supervisor: Dr. Imtiaz Madni

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Abstract

Population growth associated with increased energy consumption and the finite nature of fossil resources has led to the need to investigate sustainable energy alternatives. Biofuels emerge as an answer to this need. Biodiesel is used as a suitable substitute for conventional diesel as it is a renewable fuel obtained through the transesterification process from raw materials such as vegetable oils; animal fats and used cooking oils.

It is a liquid and renewable fuel, which has a higher combustion efficiency when compared to diesel and has many advantages both in environmental and operational terms, because it is biodegradable, non-toxic, has reduced flammability and allows better lubrication of the engine increasing its lifetime and reducing the need for maintenance.

This project aims to present the biodiesel production process, mainly the basic catalysis transesterification process using industrial automation to optimize the manufacturing process and the quality of the biodiesel produced at small-scale.

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List of Acronyms and Abbreviations

EIA	Energy Information Administration
ASTM	American Society for Testing and Materials
WVO	Waste Vegetable Oil
PLC	Programmable Logic Controller
HMI	Human Machine Interface
FAME	Fat Acid Methyl Ester
OH	Methanol
NaOH	Sodium hydroxide (Basic catalyst)
GLOL	Glycerol
CTU	Count Up Instruction
CTD	Count Down Instruction
CONV	Conversion Block
DDE	Direct Data Exchange
OPC	Open Platform Communications

Chapter 1

1. Introduction

There is a great concern today about the almost complete dependence of transport on liquid fossil fuels such as gasoline, diesel or other petroleum derivatives. In addition, oil is only extracted in certain regions of the planet, where many of them are in conflict. Information provided by EIA presented graphs showing that the maximum oil production is between 1996 and 2035. That is, in the coming years, this information only indicates a drop in oil production without growth observation. With the decline in the availability of fossil fuels in the market, research into alternative fuels may help to continue the use of liquid fuels by means of transportation.

Alternative liquid fuels include biofuels. The term biofuel or bio-renewable fuel refers to solids, liquids or gases that are predominantly produced from biomass. Liquid biofuels fall into three categories: bio alcohols, vegetable oils and biodiesel.

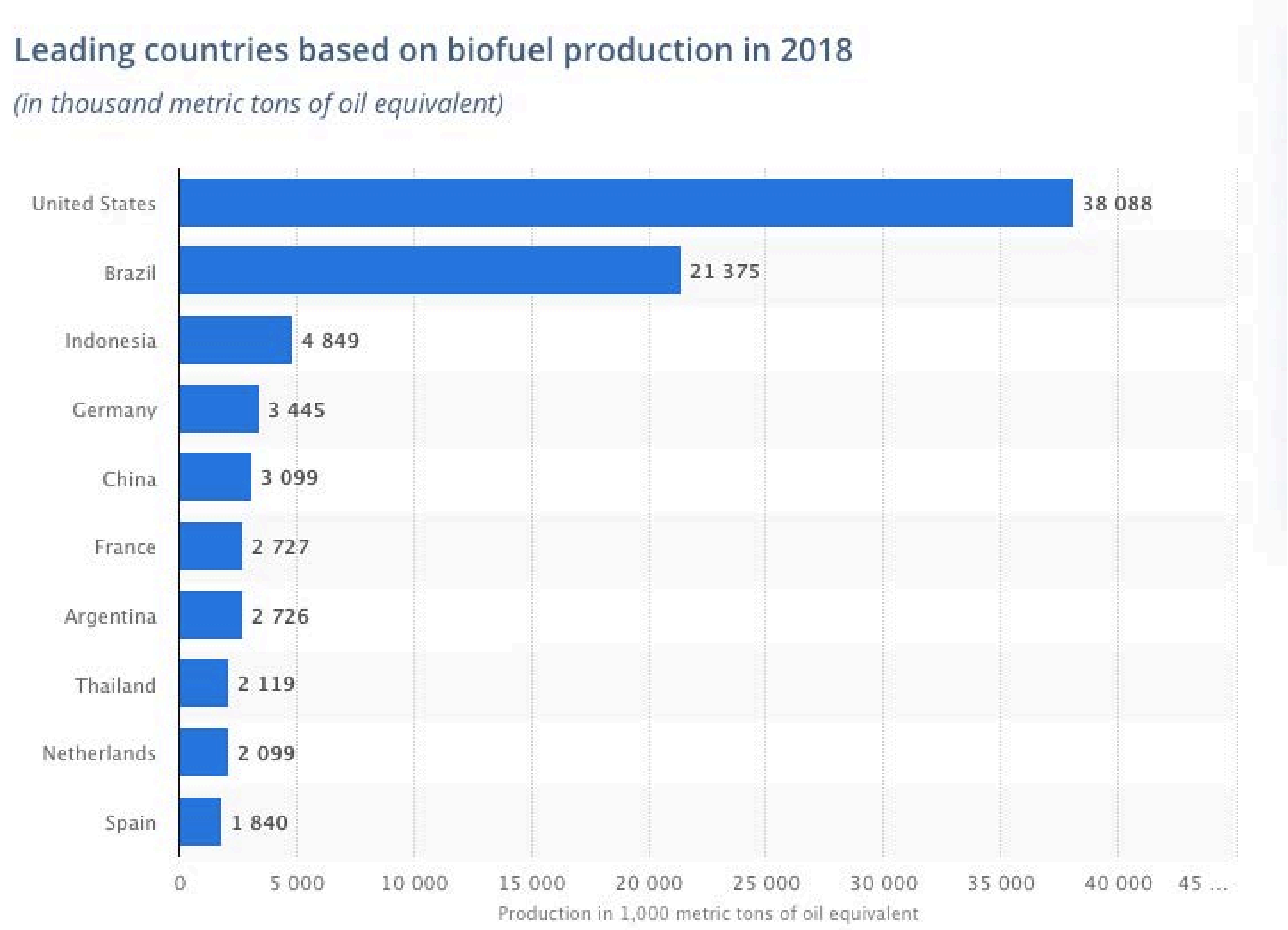


Figure 1 – Biofuel Production [1]

The two main types of biofuel currently being produced in Australia are biodiesel and bioethanol, used as replacements for diesel and petrol (gasoline) respectively.[2] As of 2017 Australia is a relatively small producer of biofuels, accounting for 0.2% of world bioethanol production and 0.1% of world biodiesel production.[3]

In 2016-17, biofuels contributed only 0.5% of the total liquid and gaseous transport fuel energy mix in Australia.[3]

Total commercial biofuel production for 2018 is estimated at 290 million liters (ML): 250ML of ethanol and 40ML of biodiesel [4].

1.1 Biodiesel

Biodiesel emerges as a renewable alternative, contributing to the reduction of dependence on petroleum derivatives, more specifically mineral diesel. It is a liquid and renewable fuel that has higher combustion efficiency compared to diesel and has immense environmental and operational advantages as it is biodegradable, non-toxic, has reduced flammability and allows better lubrication of the engine, increasing its life and reducing the need for maintenance.

The creation of the first efficient diesel engine dates from August 10, 1893. It was created by Rudolph Diesel in Augsburg, Germany. A few years later, the engine was officially unveiled at the World's Fair of Paris, France, in 1898. The fuel then used was peanut oil.

Biodiesel is a fuel that can be blended with diesel or used pure in automobiles and machines. Vegetable oils such as canola, sunflower or peanut, although very similar to petroleum diesel, cannot be directly applied in automotive engines because they are more viscous, so these oils must have their viscosity changed in order to be able to use them in diesel cycle engines [5]. However, it has low sulfur content and can be considered biodegradable. When mixed in proportion with ordinary diesel it becomes more easily accepted by combustion engines and the viscosity of diesel / biodiesel blends increases the higher the ratio of biodiesel to diesel [6].
Interest in biodiesel has recently grown because it is easy to produce and more environmentally friendly than ordinary diesel.

In order for biodiesel to be obtained, a transesterification reaction is required, the most commonly used method. In this reaction, fatty acids present in vegetable oils or animal fat react with small carbon chain alcohols (ethanol, methanol or propanol) together with a catalyst to form a different sized ester (biodiesel) and glycerol as shown in the scheme of Figure 2.

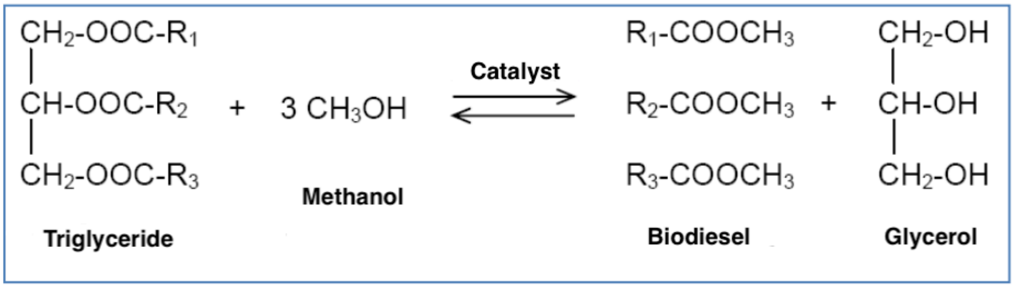


Figure 2 - Transesterification reaction [7]

The catalysis employed in the transesterification reaction shown in Figure 2 may occur in alkaline, acidic or enzymatic medium. The stoichiometric ratio of the biodiesel production reaction is three parts alcohol to one part triacliglyceride present in vegetable oil, thus preserving the Le Chatelier Principle. The catalyst that will be applied and studied in the modeling of the biodiesel plant in this work is sodium hydroxide, a strong base [8]. However, there is a caveat regarding the use of the basic reaction, because it has sensitivity to water present in oils, which can react to form soap and water instead of biodiesel (saponification reaction). Thus, vegetable oils containing less than 5% fatty acids are more suitable for obtaining biodiesel. Another interesting point for biodiesel production is to decrease the amount of water in the reaction, as it can affect catalyst efficiency and reduce reaction conversion [9].

1.2 Small Scale Production

Attention to small-scale biodiesel production has grown a lot in recent years. Not only amateurs or those interested in the subject, but many universities also use small biodiesel plants for specific purposes. Since the chemical process is the same as on an industrial scale, experiments and research can be performed on a smaller scale to validate studies. Much research has been done with different types of feedstock, or small changes in the steps of small plant biodiesel production. For example, the study by THANH, [10] where the author modifies a plant of this size by adding an ultrasonic stirrer to the reaction tank in order to speed up transesterification. Also the study by SKARLIS E. KONDILI, [11] which presents the economic aspects related to the application of a small biodiesel plant in rural areas, on the Greek island of Crete. In this work, FORE PAUL PORTER, [12] the author studies the overall energy balance of a small-scale canola oil-based biodiesel plant. These are just a taste of what can be done with these small-scale plants.

Small-scale production is generally handcrafted and small plants are usually operated by the producers of the raw material used. The biodiesel produced by them is usually of low quality, not reaching the quality standard demanded by the international fuel production normalizing agents, ASTM. There are several proposals for biodiesel production plants, some of them produced in series and others on demand. Among the small-scale plants on the market stood out the small-scale biodiesel production plant designed by KEMP [13] in his book Biodiesel: Basics and Beyond. In this book the author writes about the trajectory of biodiesel since the beginning of research on the use of biodiesel as a vehicle fuel, going through the problems that excessive use of fossil fuels can usually culminate in the chapter where he describes his biodiesel production plant.

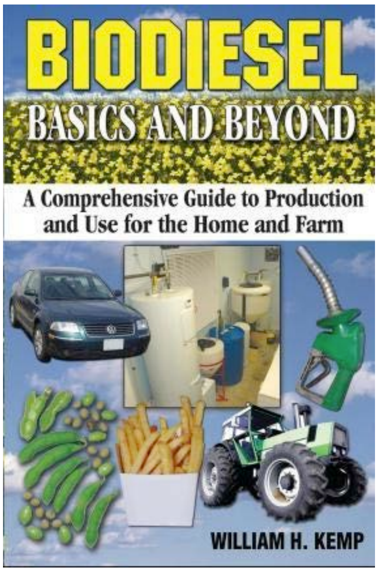


Figure 3- Biodiesel Basics and Beyond [13]

While there is no doubt that few home-scale producers are capable of making biodiesel that meets ASTM standards, there is currently no regulation or licensing of these hobbyist efforts, virtually ensuring that “off-specification” fuel is produced.

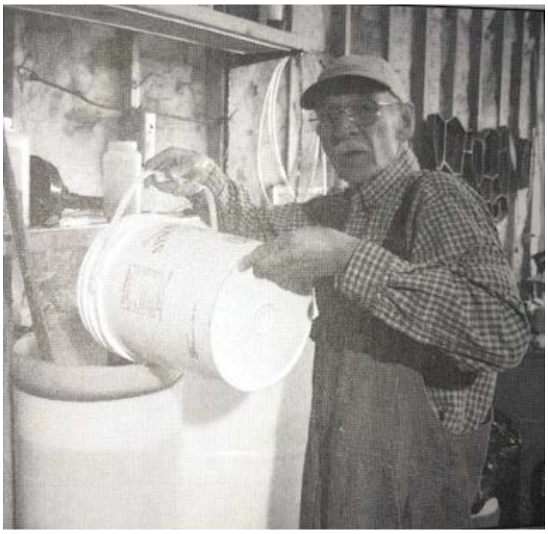
1.3 The history of Micro-Scale Biodiesel Production

In 1983, Dr Mittelbach studied the transesterification of WVO and went on to develop a commercial process to produce biodiesel from the financially attractive feedstock, earning him the World Energy Globe Award in 2001 and World Climate Star in 2003.

1.3.1 Micro-scale production studies

Steve Anderson

Over the last few years, Steve has produced a couple of thousand gallons of raw biodiesel in his workshop. He uses a very simple one processing unit fabricated from an old oil drum to produce his biodiesel. Steve estimates that he has invested about U$500 in his setup. His workshop has very little complex machinery or equipment to produce raw biodiesel. The whole process is manual and the quality of his biodiesel depends on his ability to mix the raw materials and control the process [13].



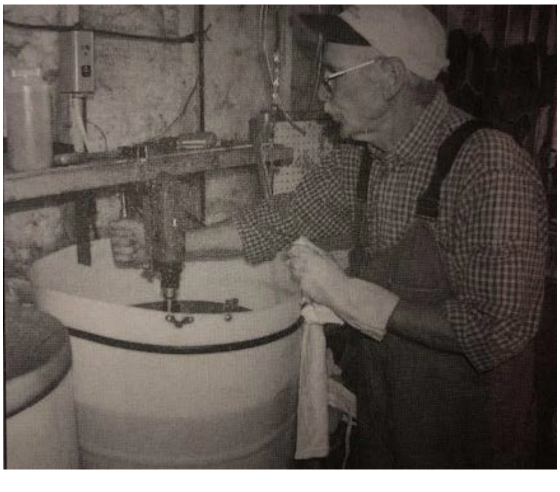


Figure 4 and 5 - Steve Anderson and his workshop [13]

Dave Probert

Dave’s original processor was built with the obligatory water heater to heat the WVO as well as with a settling/wash tank fabricated fro 55-galon drums, equipped with a circulating pump, filter, numerous valves, and fittings. The entire processing system was assembled in an insulated cabinet that was mounted on casters so it could be kept warm and rolled out of the way when not in use. Actually, he purchased a new single-cylinder diesel engine manufactured in India. He integrated it into the biodiesel production process by using my biodiesel fuel to power the engine, which in turn drives a generator to power the biodiesel processor. The whole process is manual and the quality of his biodiesel depends on his ability to mix the raw materials and control the process [13].

Figure 6 and 7 - Dave Probert and his workshop [13]

Dan Freeman

Dan owns and operates his fuel retail and distribution business, Dr. Dan’s Alternative Fuel Werks, alongside his automotive repairs shop. He started in 2001, selling ASTM B100, primarily from West

Central and has watched sales grow up to around 15.000 gallons per month. He has hundreds of clients who regularly fill up with B100, including operators of heavy equipment from bulldozers to tractors. He started a web-based survey ate the end of 2003 and have documented well over a million miles of trouble-free driving using B100. The whole process is manual and the quality of his biodiesel depends on his ability to mix the raw materials and control the process.

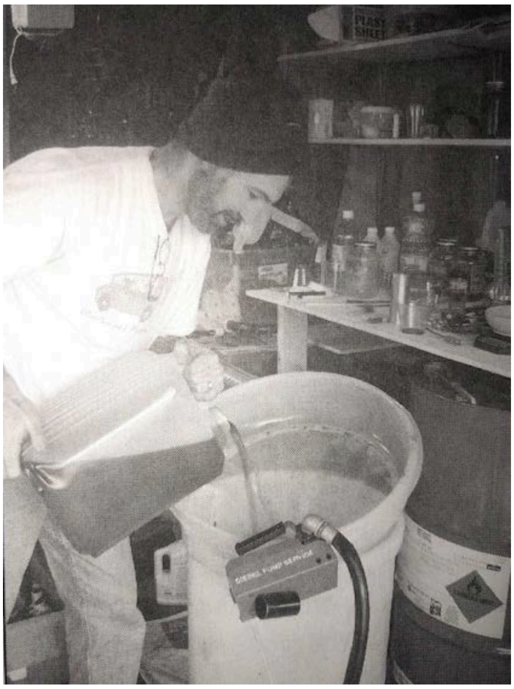


Figure 8 - Dan Freeman and his workshop [13]

University of Brasilia

An example of manual production is the existing biodiesel pilot plant at the University of Brasilia campus Gama. This plant has a production capacity of between 50 and 200 liters per day when in operation, and is used to teach college students about biodiesel production in Engineering courses.

Figure 9 - Small-scale biodiesel production plant at the University of Brasilia.

2. Problem description

The biodiesel production process can be divided into five main parts: drying of the raw material, addition of reagents, transesterification (chemical reaction), glycerol removal and final product purification. These steps are performed manually. This level of production affects the quality of the end product, low productivity and expense during production, which makes the manufacturing process slow and under control. To improve these aspects, automating some of these steps would be a way of providing process improvements. Thus, of the five mentioned steps four will have their processes automated, they are: drying of the raw material, transesterification, glycerol removal and purification of the final product. The process of adding the reagent, methanol with the catalyst, will not be simulated. The catalyst is sold commercially in solid form (powder or small stones) and as only hydraulic pumps will be used in the system, it is not possible to automate the addition of these chemicals to the system.

3. Justification and contribution

One of the biggest advances in industrialization was the implementation and development of automation and control in industrial processes. Keeping up with these technological advances is essential to be up to date on the planet's economic growth. So getting involved in jobs that propose development of automation projects is an important step for the professional career of the engineer. Industrial automation has numerous fields of application, from, for example, the automotive industry to the automation of chemical production through various other sectors of the economy. Some core elements in automation are common in different projects, making knowledge of one project contribute to application in others. In the present work we will develop a small-scale biodiesel plant automation project, a project in the chemistry area that presents the central elements of automation, making the conclusion of the work consolidate the basic knowledge in automation. This work is justified in the goal of partially reducing the inefficiencies in the operation of manual plants. Biodiesel hand plants can produce useful fuel, but the quality of the final product varies greatly from batch to batch. By applying automation design with actuators, sensors and controllers it is possible to increase the quality of operation and consequently the quality of the final product. Sensors, valves and actuators will be simulated as well as the values of system volumes and operating temperatures. The final product will be a program that will emulate the operation of a biodiesel plant contributing to the future development of a possible mobile small-scale biodiesel production plant automation project.

4. Objectives

Design small-scale methyl transesterification biodiesel plant automation system in which sensors, actuators, and tank volume and temperature variables are simulated in PLC to improve production process and quality of the Biodiesel.

4.1 Specific objectives

- Build flowchart describing the process of biodiesel production proposed by Kemp in his book.
- Develop Ladder code in RSLogix 5000 software that simulates in PLC the flowchart presented in the previous item.
- Design complete supervisory control and data acquisition (SCADA) system in FactoryTalk View software.
- Simulate the Temperature and Volume variables of the biodiesel production process within the PLC.
- Simulate valves, hydraulic pumps, heaters and all actuators present in the system.

5. Work organization

This work is organized as follows: Chapter one, Introduction where the reader is updated on the state of consumption and production of renewable fuels, with emphasis on the production of biodiesel and general objective and specific objectives of the work are presented. Chapter two contains the literature review that covers the theoretical framework needed to understand the manuscript: This chapter begins by introducing concepts in industrial automation such as: the automation pyramid, describes some sensors and actuators that will be employed in the plant, describes concepts of organization with emphasis on diagrams for commercial and industrial use. The same chapter goes on to learn the advantages of correctly applying automation in real industrial processes, with examples of success. The chapter ends with the theoretical referential in chemistry of biodiesel production and the fuel production scales are presented. Chapter three covers the methodology employed at work. This chapter will describe the details of the project developed and also present the small-scale biodiesel production plant that was developed in computer and programming details at the programmable logic controller (PLC) level. The work ends in chapter four where the hypothesis, results and conclusion extracted from the biodiesel production plant project are presented.

Chapter 2

6. Literature review

The first diesel engine operations using vegetable oil were carried out by the French company Otto during the World Fair in 1900 [14]. The engine operated with peanut oil, without any modifications, at the request of the French government, which envisaged the possibility of using this type of oil for energy production, as this plant was produced in large quantities in African colonies.

Diesel (1912) stated, even at the beginning of the last century, that diesel engines can work with peanut oil without major difficulties, being this oil practically as effective as mineral oils, and can be used as fuel oil and lubricant at the same time, making the engine an independent machine, ideal for tropical countries. The author also mentions the use of castor oil and animal oils in locomotives in experiments conducted in the city of St. Petersburg. Back then; Diesel claimed that engine power could be produced from the heat of the sun, which would always be available for agricultural purposes, even when all stocks of solid and liquid fuels were depleted.

According to Knothe, Gerpen and Krahl, in several articles published in the 1940s, they cite the use of palm oil as a fuel source. According to the authors, several countries that had African colonies, such as Belgium, France, Italy and the United Kingdom have shown interest in the development of vegetable oil derived fuels. The authors further comment that during World War II vegetable oils were used as emergency. Projects of the time, carried out at the State University from Ohio, USA, investigated the use of cottonseed oils, corn and mixtures with conventional diesel oil. The same authors cite that after the war, Indian researchers expanded their research to 10 new types of vegetable oils for the development of domestic fuels [14].

Biodiesel is defined as a fatty acid alkyl ester obtained from the transesterification reaction of any triglyceride (oil and vegetable or animal fats) with short chain alcohol. Transesterification is the chemical reaction of a vegetable oil with an alcohol, which may be ethanol or methanol, in the presence of an acid (hydrochloric acid) or basic (sodium hydroxide) catalyst. As a result, methyl or ethyl ester (biodiesel) is obtained, depending on the alcohol used, and glycerin [15].

Therefore, transesterification is nothing more than the separation of glycerin from vegetable oil. During the process, in which the vegetable oil is transformed into biodiesel, glycerin, which makes up about 20% of the vegetable oil molecule, is removed (leaving the oil thinner and reducing its viscosity), being replaced by alcohol from ethanol or methanol. Glycerin, a byproduct of biodiesel production, can be used as a raw material in the production of paints, adhesives, pharmaceuticals and textiles, increasing product competitiveness.

6.1 Automation pyramid

During the automation development process there was a growing need for integration between command and performance in manufacturing processes, generating a hierarchy of command functions in the automation of industrial processes. Such hierarchy can be visualized in the form of a pyramid and this has been called the automation pyramid.

The automation pyramid hierarchically organizes the levels of information control within an industrial automation system. The closer to the top, the greater the amount of information and the more elements controlled by the equipment present at that level. The dimensions of the pyramid levels are proportional to the amount of elements present in the level. The description is presented below in list form where each level of the pyramid is described [16].

- Level one. The base also includes shop floor machines, plant components and task equipment. Actuators at this level are presented individually. In order to communicate with the level above, a communication platform is used.

- Level two. Level where the programmable logic controllers (PLC) and other automatic control equipment for plant activities are located. This level is called the control level.

- Level three. This level is called the supervision level, where the process databases are located and where the production process optimizations are applied, and the production reports and statistics are produced and stored. Through the site intranet it is possible to reach level four of the automation pyramid. This is where the HMI is presented.

- Level four. Considered the level of production scheduling and planning, the control and logistics of supplies are performed.

- Level five. Finally, the last level, located at the top of the pyramid, is the company's sales and management software. This level completely controls the automation process.

The image of the automation pyramid is shown in Figure 10 below.

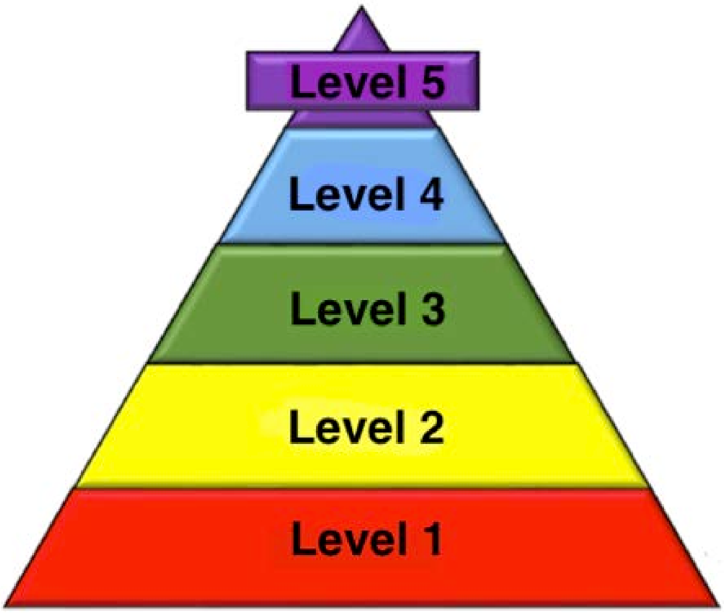


Figure 10 – Automation Pyramid

6.2 Sensors and Actuators used in biodiesel plants

For biodiesel production, some sensors and actuators typical of chemical plants are used. Some of them will be presented below.

6.2.1 Hydraulic pumps

To move any liquid, whether oil, water or any other fluid within a system, fluid pumps are used. A pump consists of mechanical equipment that converts torque from a moving electric motor of a fluid [17]. The electric motor can be turned on and off with a power switch. In KEMP’s biodiesel plant, hydraulic pumps are very important elements in the process because they act both in the movement of fluid between the tanks and in the agitation of reagents during the transesterification reaction. In Figure 11 is presented an electric motor coupled to a hydraulic pump.

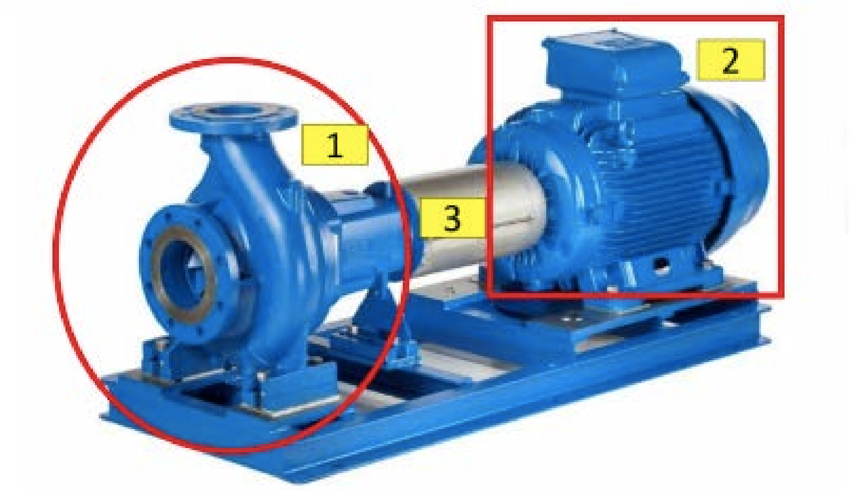


Figure 11 - Hydraulic pump coupled to electric motor. Where (1) is the hydraulic pump and (2) is the electric motor. The two are connected by an axis in (3) [18].

6.2.2 - Solenoid Valves

Solenoid valves allow the flow of fluid through the interior, as in this case, biodiesel. The passage of fluid is due to the actuation of a solenoid inside. The solenoid is a spiral-shaped electromagnetic device with a ferrous core protected by a metal cap. When electric current passes through the spiral, a magnetic field is generated that raises the ferrous nucleus, where an internal membrane is attached. Membrane movement connects the outlet with the valve inlet, allowing fluid to flow through it. At the project's biodiesel plant, the solenoid valves used have the function of modifying the direction of movement of the biodiesel.

Figure 12 - Solenoid Valve [19]

6.2.3 - Temperature Sensors & Level Meters

Temperature is a very important parameter to be controlled in almost every chemical industrial process, as it directly affects some physical properties of plant materials and the quality of manufactured products [20].

With the advancement of temperature measurement technologies, various electronic sensors have been developed for measurement in chemical systems. The two main types of thermometers are: low temperatures, with a range between -100 ∘C and +400 C, and high temperatures, ranging from 500 ∘C to 2000 ∘C. The technology behind low temperature measurement thermometers is the use of phosphor sensors along with semiconductors or liquid crystals. The measurement made by this type of thermometer is made by the contact of a sensitive rod where the temperature is to be measured. High temperature thermometers, by contrast, work through quantum effects related to blackbody radiation. An example of low temperature measurement thermometer can be seen in Figure 13 below. When measuring oil in tanks, low temperature thermometers are generally used as most oils evaporate [21].

Figure 13 - Example of industrial thermometers [22]

6.2.4 - Programmable Logic Controllers

The PLC was invented in 1969 by Modicon due to the high demand from the automotive market to change the control parameters of its plants, which were controlled by relay logic. Logical changes during the period when relay panels were used, as shown in Figure 13 below, took a long time because the physical change of equipment at the factory was required. This problem originated the movement that developed what would become the current PLC. The PLC uses the same ladder sequence logic as relay panels but virtually.

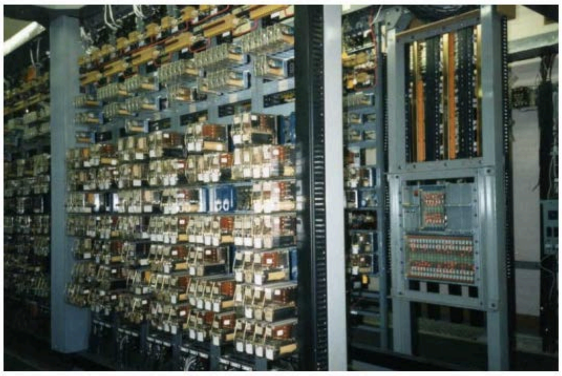


Figure 14 - Relay Panel being used in industry [23]

The big difference from a PLC to a regular computer is that it is designed to work in environments with heavy demand for hours of use and harsh conditions, and has a wide connectivity that can be seen by the large amount of inputs and outputs present in the PLC. It is modular equipment expandable to the limit of inputs and outputs allowed for each model. Because it is modular, it is usually mounted in a rack, where the modules required for the intended application can be added, as shown in Figure 15 below.

Figure 15 - Example of S7 1200 PLC produced by Siemens [24]

A typical PLC is basically divided into two parts: a central processing unit (CPU) for processing, and an input and output interface. Inside the CPU there are two types of memory: Electrically-Erasable Programmable Read-Only Memory (EEPROM), which preserves its contents even when the PLC is off, saving it as the address of the sensors on the device inputs and outputs. Also in EEPRON are stored the commands that the PLC will play, which input will be read (digital or analog), and in what order. RAM (Random Access Memory), random access memory is erased once the PLC power is turned off, it is in this memory that sensor state data is saved during PLC operation and variable values obtained during the operation of the PLC [25]. The inputs and outputs of a PLC are removable, so that the same controller can be used in various situations and adapts to the demand of a variety of sensors or actuators depending on the design [26].

The PLC inputs are divided into analog and digital. Digital inputs receive only two states, binary, or one, or zeros. Analog inputs receive a range of varying states so analog inputs are used to receive volume or liquid level sensors as they must read a large range of values, while digital inputs receive on and off buttons or end sensors where there are only two states The controller outputs are either digital or analog outputs and are also inserted into the PLC through a cartridge. The electronic contacts are coupled to the actuators that will be controlled by it, such as motors, light emitting diodes, thermal resistors and hydraulic pumps.

6.3 - Ladder Logic

The use of relays to create a set of logic functions within a system has forced users to develop their own programming language that facilitated the construction of automation programs. This language was called Ladder.

Ladder graphical language is the logic between inputs and outputs that perform the desired functions according to their state. Electronic elements are represented by symbols as shown below in Figure 16.

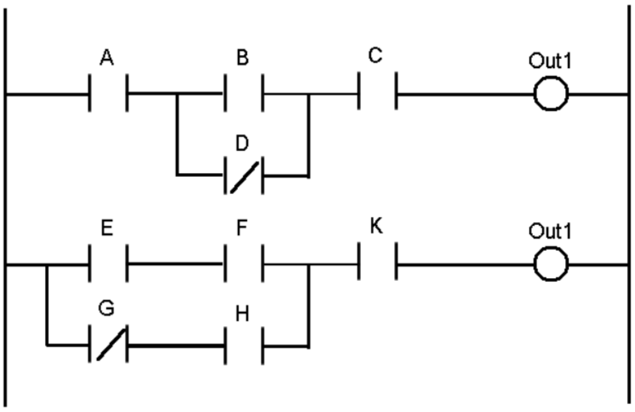


Figure 16 – Ladder logic [27]

6.4 Supervisory Control And Data Acquisition

Supervisory Control And Data Acquisition, or SCADA, is a software system that controls and supervises industrial systems by acquiring system data and sending commands to the system in an exchange system [28].

SCADA systems are typically divided into two modules with distinct features and functionality:

1. The development module

2. Execution modules or runtime, which, as its name implies, runs the developed system.

The development modules of all SCADA software have a graphical interface for the purpose of creating objects with or without animations for the representation of the process whose purpose is monitoring.

To monitor and control industrial systems, SCADA software must have the ability to communicate with equipment. For this, the applications provide communication modules, which are provided with a large number of drivers, so that information exchange with equipment between different manufacturing companies is allowed. Data communication being efficient is the critical point of this type of system. In this way commands can be made to drive electric motors, valves, pneumatic and hydraulic systems, hydraulic pumps and a multitude of elements. This is also how we can view measured values through sensors [29].

One point of attention, however, is that the supervisor does not make any kind of decision making that allows automatic control. This type of control is usually performed via PLCs. SCADA systems also have tools to track the activities performed by system users, as well as to display diagnostics of equipment failures or production process steps.

The main information received by the supervisor is stored in a database, so that it is available for later consultation by the user. This information is used to generate alarms indicating system failure or malfunction, as well as events, to indicate any event relevant to system operation. In the case of the biodiesel plant the alarms are the valleys of temperature and volume of the tanks. Being able to visualize the sequence in which events occurred in the system is an important tool for diagnosing the root cause of problems in an industrial plant.

With the information received in real time, it is possible to verify how it behaves graphically over time, which allows us to perform an analysis of the information trends and predict the system behavior in future situations, or even identify past failure points. With this information available and stored by the SCADA system can also be used to generate reports. Many applications have custom reporting functions where you can create a PDF file with the information you need [29].

6.5 Diagrams

6.5.1 Process Flow Diagram

According to Frank Gilbreth - the creator of the first process diagram - the definition is a tool for visual organization of elements within a project. Before any events in a project can run, you must arrange the order in which they will be used. For this to happen, we use a didactic process diagram that allows the visualization of the task and the component that performs it.
This diagram is also a visual representation of the sequence of tasks that must be followed until the end of the process, very similar to a flowchart [30].

These diagrams can be used in both academic and industrial activities. In computer programming, as in the case of object-oriented language, its use is to organize the function blocks that the code must execute before the algorithm is programmed into the machine. In chemical industrial processes, for example, process diagrams are used to organize the sequence of components and chemical reactions of each production phase, providing insight into the actuators required at each stage and where they will be used.

6.5.2 Instrument Diagram

The instrument diagram provides a graphical representation of the instruments used in a process. This includes piping, tanks, actuators, sensors, and controllers that actuate or read the system to describe the process performed. The diagram covers: inputs, outputs, and quantities of each instrument and composition in the system. The instrument diagram also shows important information needed to operate and build the system, such as the physical dimensions of the devices used and the overall size of the system. The instrument diagram also has the literal description of each component and the system block diagram, as well as the electrical diagram (cables and wires of each equipment) and the command logic, all in one figure. Your information is transmitted through your images and so they contain few texts. In the industry, the instrument diagram is used as the primary document for locating components within factory environments, as well as having site safety information.

Figure 16 shows an example instrument diagram of a generic biodiesel production plant with valves, tanks and pumps. Arrows represent the directions in which chemical reagents travels during the operating process. The valves and pumps have their own design standardized by the International Organization for Standardization (ISO), which sets the standards for standardization of symbols and figures of industrial organization.

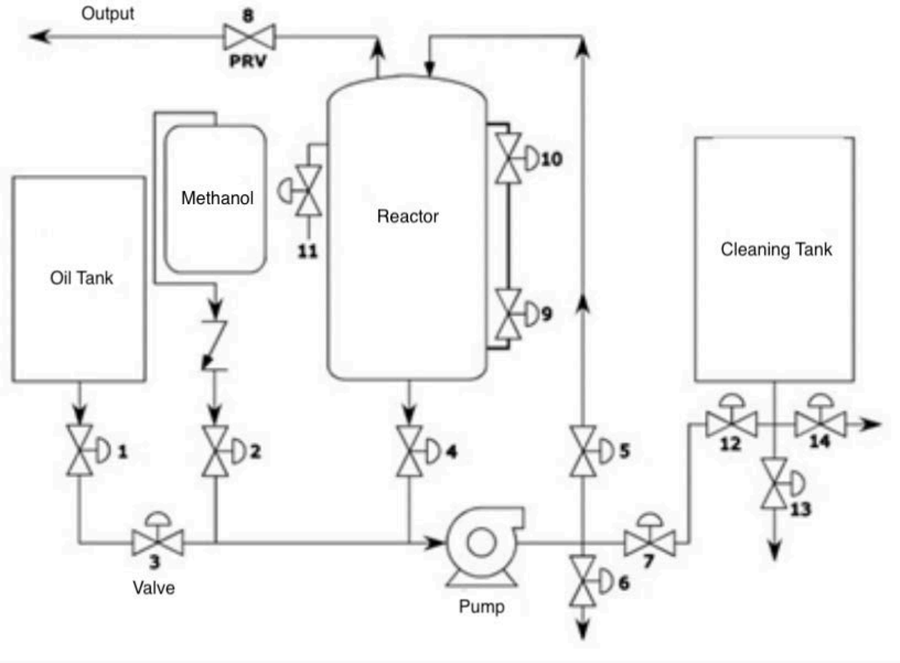


Figure 17 - Example of instrument diagram of a generic biodiesel plant. Adapted by the author [31].

6.6 Previous studies

In the master's thesis of WORM, the author elaborated automation project in an existing manual production plant in his university. The plant he used in his project also used the methyl route for biodiesel production and, as a reagent, vegetable oil. However, this plant had a double transesterification process, that is, the vegetable oil passes twice through the chemical reaction tank and this increases the amount of fuel produced. The project has no well-developed supervisory system, only a small screen to monitor the operation coupled to a PLC, which informs which stage is the process, and some alarms. In its design, the actuators are only pumps and heaters. The valves, however, continue to be manually operated, having only one coupled sensor that informs the PLC of their closed or open position [32].

In the article by BIRCHAL, the authors had access to a semi-automatic biodiesel production plant in laboratory production quantities. The plant was originally used in research to discover biodiesel production potential using different reagents, oils or catalysts. In the authors' work, a programmed supervisory process control system was designed to modify reaction conditions, time and temperature. The authors' plan is used in research and the user can, through the supervisor, modify the reaction time and temperatures for each type of oil used [33].

In the Americans' article ELSAWY, the authors, university professors, proposed to their undergraduate students the design and assembly of an automated biodiesel production plant for approval in the discipline. However, in the automation requirements, the control of the transesterification reaction is expected to be adaptable for each type of oil used. For this it is necessary to perform oil titration process even before its insertion in the plant. The pH values are compared with a table and the reaction temperatures entered into the system. Only the process of placing methanol in contact with oil is manual, by means of a manual siphon. All other transports are made by hydraulic pumps [34].

The work of MALONE MATTHEW HOLMAN was to create a biodiesel production plant by methyl route with just one transesterification step. The process has no supervisory system and all automation command is performed by the PLC. Actuators are pumps, heaters and valves. In this plant biodiesel is stirred during the reaction. Mixing is by means of an ultrasonic stirrer operated by the PLC [35].

In addition, many scholars of autonomous biodiesel production propose biodiesel plant designs in home fuel production books. This is the case of the plant that will be used in this work where the proposal of KEMP will be examined and worked on.

For this, the plants usually have two tanks, one for cleaning the oil that will be used and another for the transesterification reaction. Some more elaborate plants propose another tank where the catalyst is mixed with the alcohol before it comes in contact with the oil in the reaction tank. Others even have a device for receiving alcohol that has not reacted with the oil.

The process used at University of Brasilia the plant to obtain biodiesel is the transesterification of crude or frying oil collected in the city of Gama. The process is based on a few steps, which can be described below:

- First, unfiltered oil is inserted into the catchment tank where it is filtered to remove large particles, usually pieces of food present in the oil.

- It is then heated to remove traces of water that may be present in it.

- The alcohol is mixed with the basic NaOH catalyst in a tank of its own and this mixture is then placed in the filtered oil tank and stirred by paddles.

- After the reaction occurs, the mixture is taken to a decanter tank (last tank of the plant), where the denser glycerin is deposited at the bottom and subsequently decanted and stored.

- Alcohol vapors are reused in the process by condensation. Liquid alcohol is stored in its own tank and can be reused.

- In the reactor tank, newly formed biodiesel without glycerin is taken to final water cleaning processes where the "acid", "basic" and "neutral" cleaning tanks are used for final product purification. In the acid tank, the bases in the product are neutralized. The "basic" bath does the same, but with acids. “Neutral” cleaning dilutes remaining soluble substances. The bath waters are removed by decantation due to the density difference between them and biodiesel.

6.6.1 Flowchart University of Brasilia process

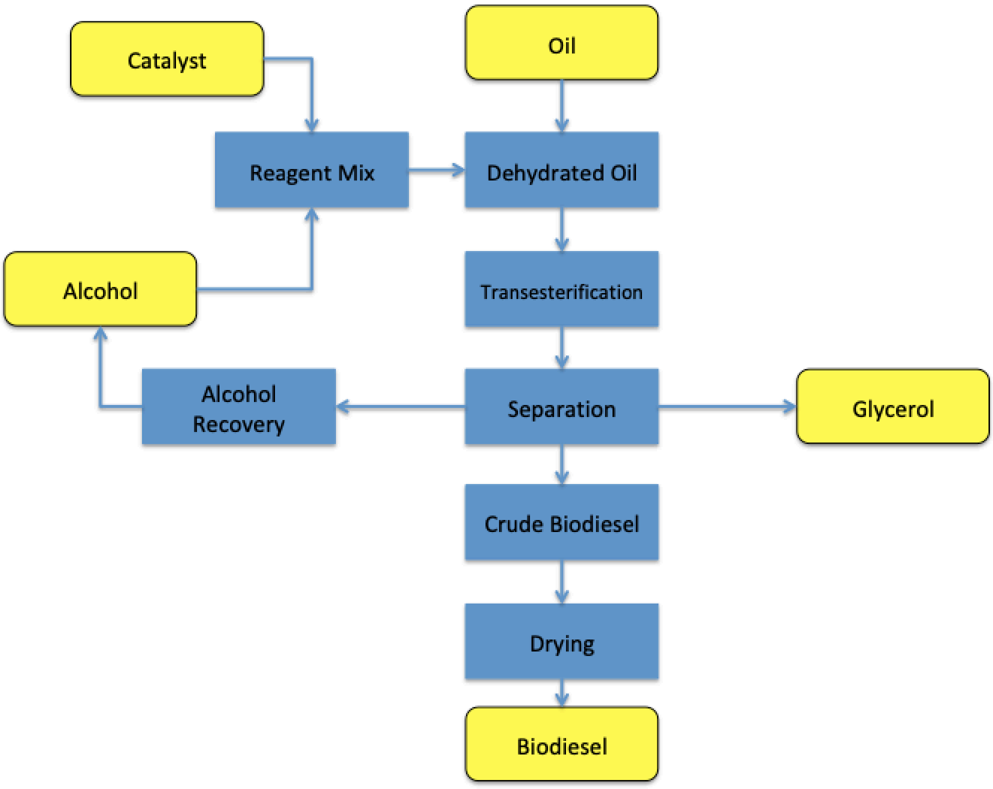


Figure 18 - Simplified flowchart of manual biodiesel production with methanol reuse.

Chapter 3

7. Methodology

H.R. Kemp's book Biodiesel Basics and Beyond was chosen to deepen knowledge of small-scale biodiesel plant design. In the work, the author describes in detail his project for a small-scale biodiesel production plant. From the step-by-step biodiesel production described in the book the flowchart was extracted. The flowchart is a step organization tool in a process that allows it to be performed without errors if the steps are correctly followed. With the flowchart it was possible to identify in which steps and which types of sensors and actuators to be used.

In parallel with the development of the flowchart, theoretical research in chemistry on biodiesel production was carried out through papers published in renowned journals, since the book by does not have sufficient academic basis. With the results of the research, the initial chapters of this document were prepared, containing background information on biodiesel production ensuring the necessary academic support for this publication.

The same flowchart was transformed into ladder logic using RSLogix 5000 software. Each step has been translated into lines of program code guiding the software to perfectly comply with what (KEMP, 2006) described in its book. Each sensor and actuator described was implemented in the algorithm transforming the manual steps into actions of digital actuators that were simulated. For the developed software the following requirements were stipulated:

- Pump vegetable oil into the evaporation tank;
- Circulate the oil inside the tank;
- Pump the oil out of the tank;
- Coordinate the operation of related valves;
- Measure the oil level inside the drying tank;
- Check that the reaction system valves are in the correct positions;
- Check the temperature throughout the process;

After the drying process, the purified oil goes to the reaction tank. In the second tank of the plant occurs the transesterification reaction where biodiesel appears in the process. Reaction tank requirements are:

- Check tank oil volume;
- Check valve position;
- Pump methanol into the tank;
- Check methanol volume;
- Monitor reaction temperature;
- Perform reaction pumping;
- Operate the heater to achieve the temperature values set for that tank
- Check position of valves for glycerol removal;
- Monitor final volume of biodiesel produced without glycerol;
- Check that the methanol heat exchanger is on;
- Pump biodiesel into the filtration tank;

Crude biodiesel finally goes to the filtration tank where it is purified for use. Before entering the tank biodiesel goes through a cleaning process with water and air bubbles. Reservoir requirements for all final filtration and cleaning processes are presented below.

- Operate the air compressor (to make air bubbles);
- Operate the water sprinkler;
- Check filtration tank temperature;
- Operate the circulation of biodiesel.
- Check the volume of the filtration tank.
- Operate the air heater of the third tank.
- Pumping out biodiesel.

The program made in PLC of the plant had simulation of temperature and volume variables, the implementation made in a code that emulated the variation of these quantities. To fulfill this requirement, it was necessary to use different function blocks in the program so that, when associated, they simulate volume and temperature values within the plant tanks. The variables were simulated individually, with no relationship between them. Variations in the maximum and minimum values of the generated variables were within pre-established maximum and minimum values. Then the SCADA system was made in FactoryTalk View software. At this stage all visual elements KEMP plant, tanks, valves, pipes, among others, were built within the program.

In addition to the visual aesthetics of the plant were simulated the movements of plant operation: movement of biodiesel and reagents through the tubes, increase and decrease in the volumes of tanks, mechanical stirrer blades, etc. Useful plant alarms (temperature and volume alarms) were also implemented, as well as system graphics screens and synoptic screens for each tank.

7.1 Kemp’s Biodiesel Plant information process

Tank capacity: 60 gallon (227 liter)

1 - Waste Vegetable Oil (WVO) is collected from restaurants and transferred immediately to the receiver tank.
2 - First Filtration: 1-3 hours
3 - Oil is transferred manually pumped to the tank (90L per 100 strokes) Aproxim 25L/min
4 - Heat oil to 110 °C: 1 hour (remove water)
5 - Mix methanol with *NaOH* (reagent) (20 -30 min)
6 - Transfer heated oil to reaction tank (manual valves)
7 - Add the mixture to reaction tank
8 - Heat Biodiesel to 55 °C
9 - Heat Biodiesel to 80 °C
10 - Methanol removal
11 - Separation glycerin from biodiesel (at least 8 hours)
12 - Transfer Biodiesel to filtration tank
13 - Cleaning process (2-3 hours)
14 - Heat Biodiesel to 110°C (remove water)
15 - Transfer Biodiesel to storage tank

8. Automation Project

8.1 Flowcharts

Flowcharts are diagrams that show the step-by-step progression of a process or system using specific lines and symbols. The standard for defining symbols is ISO 5807. Flow charts are widely used in the chemical industry to present the steps of a chemical process in creating a product. The symbols of a flowchart are shown below in Figure 19.

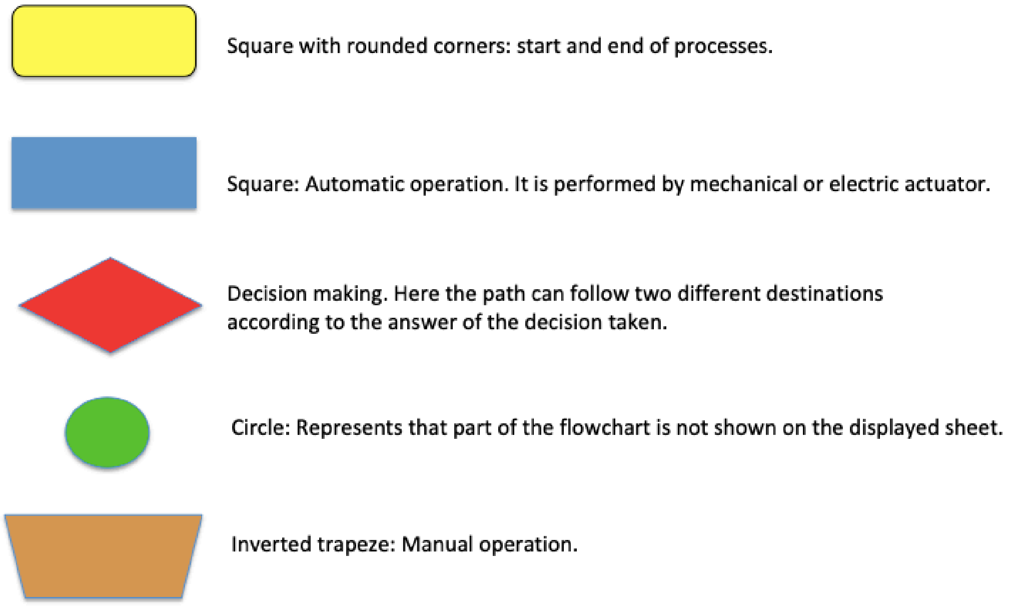
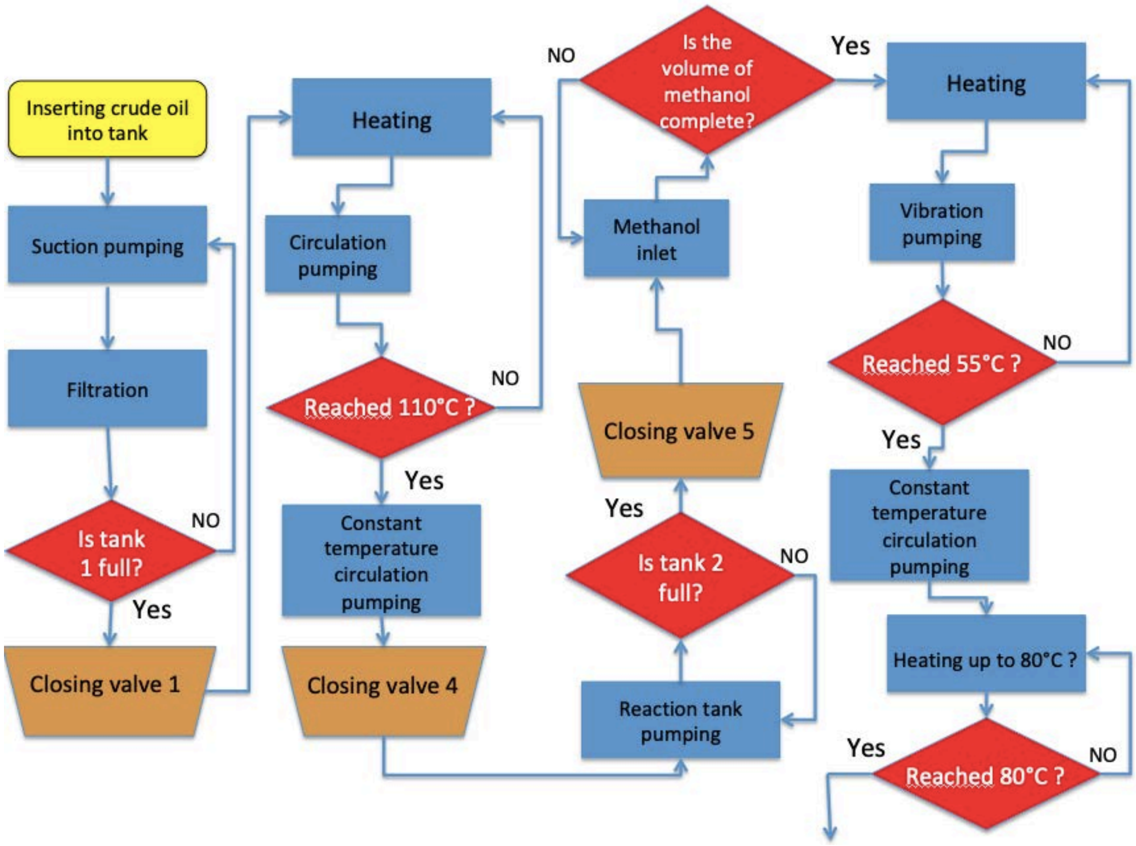


Figure 19 - Flowchart Normalization

8.2 Biodiesel Flowchart



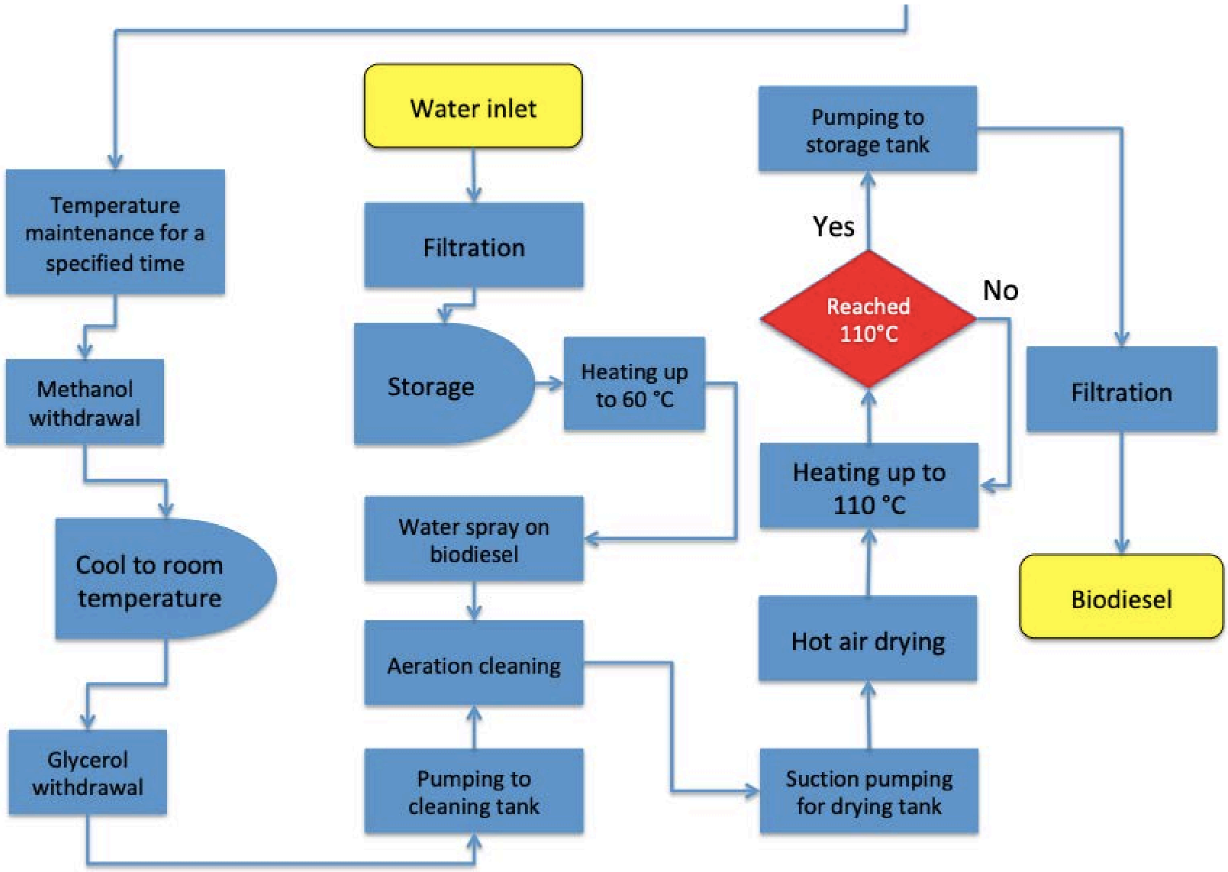


Figure 20 and 21 – Biodiesel Flowchart

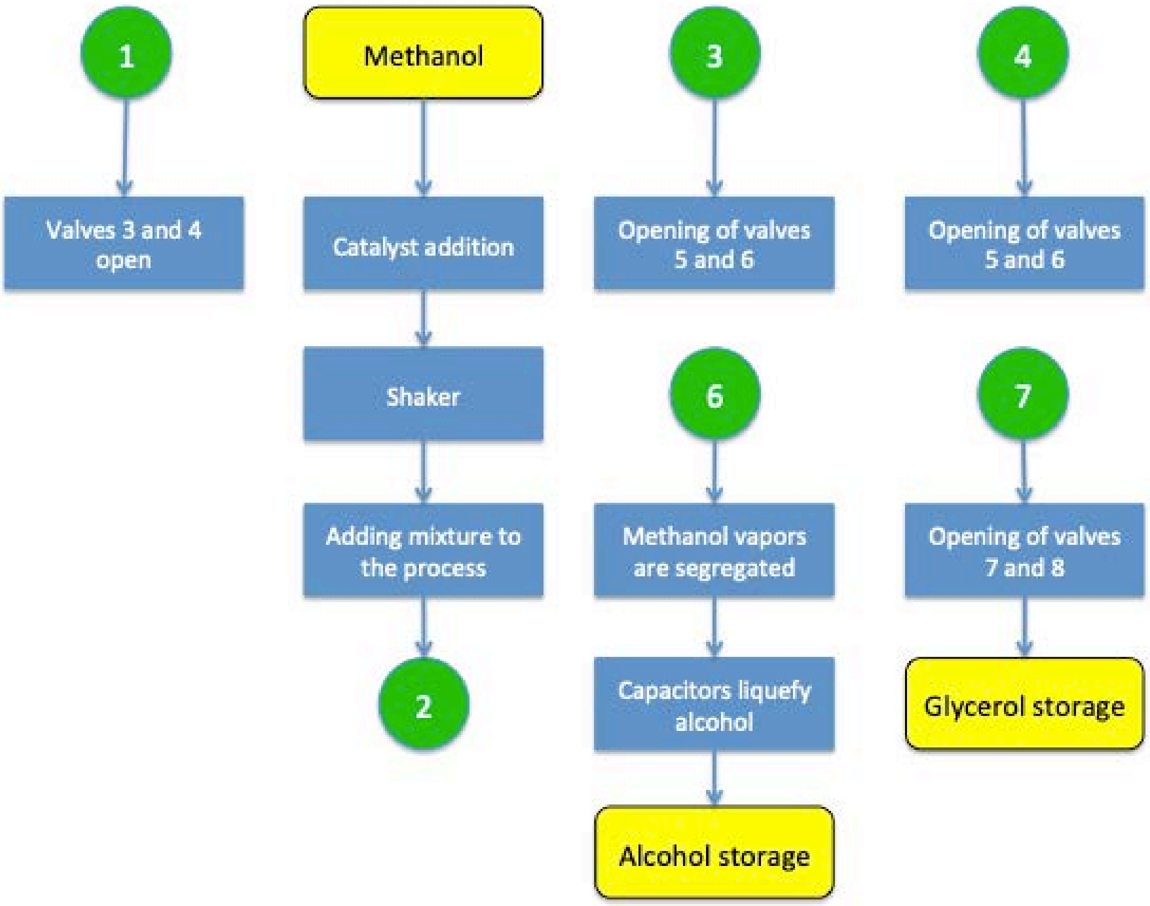


Figure 22 – Biodiesel Flowchart

The steps that are shown in Figures 20, 21 and 22 are described and enumerated below.

- **Step 1 to 3**: Crude oil is introduced into the plant by suction from pump one. This pump is coupled to automotive oil filter for raw material purification.

- **Step 4**: A block asks to know if the first tank is full.

- **Step 5**: A manual operation block shows that it is necessary to close the first valve by isolating the first tank for heating.

- **Step 6 to 9**: Warm-up cycle: With valve 3 and 4 open. Tank 1, with use and electric heaters, heats vegetable oil up to 110 ∘C for water evaporation. A decision making block exists for the system to reach the desired temperature without advancing logic.

- **Step 10**: Pumping Cycle. Once the set temperature is reached, the system continues with the pumping cycle keeping the temperature constant. The limiter is now the mass of the system. That is, until the body of water is reduced to one third.

- **Step 11 to 15**: Closing the Valve 4. The valve that allows oil to remain inside the first tank is closed and thus the oil can go to the second tank. The condition exists until the second tank sensors confirm that the volume is complete in the second tank.

- **Steps 16 and 17**: Corresponds to the methanol intake with catalyst in the system for the transesterification reaction to occur. The process is not all described only through these two steps. There is the process of adding the catalyst to methanol. This process is done manually. Number 2 describes it. Circle 2: Description of the methanol addition process. In this set of steps, methane is placed in its own tank, different from the reaction tank and together with the catalyst. A mechanical stirrer mixes the two with paddles for later insertion into the reaction tank.

- **Steps 18 to 20**: Between part 18 and 20 is the transesterification reaction itself. Here the valves required to cycle the reagents are closed. For the reaction to occur, the open or closed valves are described in circle number 3. The reaction occurs at a known temperature of 55 ◦C.

- **Steps 21 to 25**: Methanol removal. After the transesterification reaction is over, the remaining methanol can be condensed and reused. For this the internal volume of the reaction tank is heated again, now to 80 ◦C. The boiling temperature of the methanol according to IUPAC (International Union of Pure and Applied Chemistry) is about 78 ° C. Raising beyond this temperature can recover the part of methanol that did not react with vegetable oil. Through the use of a heat exchanger, methanol vapors rise from the reaction tank and are condensed and stored in an appropriate tank.

- **Step 26**: Wait until the reaction tank thermometers report that it is at room temperature.

- **Step 27 to 30**: Biodiesel cleaning step. After the glycerol is removed, the remaining biodiesel is sent to the second to last process tank, the cleaning tank. In this tank, biodiesel is cleaned with air bubbles and water vapor. With the help of a "bubbler" touched by a compressor, air is injected into the biodiesel. At the same time water jets are sprayed on the surface of the biodiesel volume. This process serves to clean biodiesel from soluble impurities present in the product.

- **Step 31 to 32**: Heating Drying. A warm-up cycle is performed so that water has entered the system during the flushing process. This process is done for a predetermined time using a fan with electrical resistances.

- **Step 33 through 35**: Final Storage. Biodiesel is pumped into the tank where it will be stored until use.

8.3 Biodiesel Plant Equipment

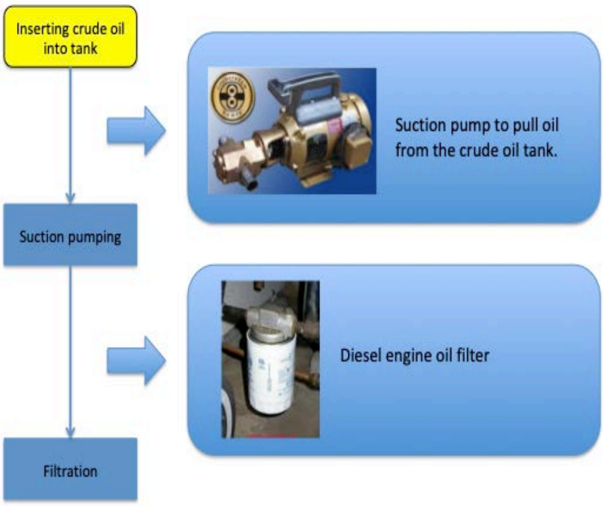


Figure 23 - Stage where pumps and filters present in the system are used.

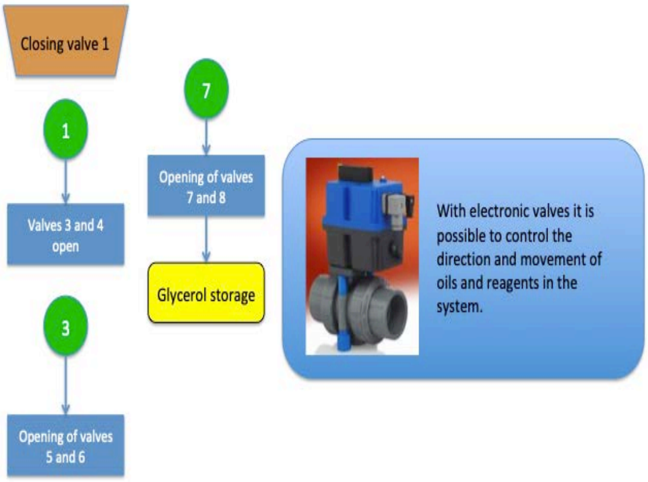
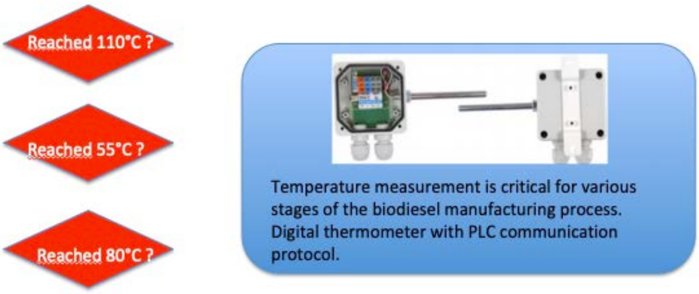
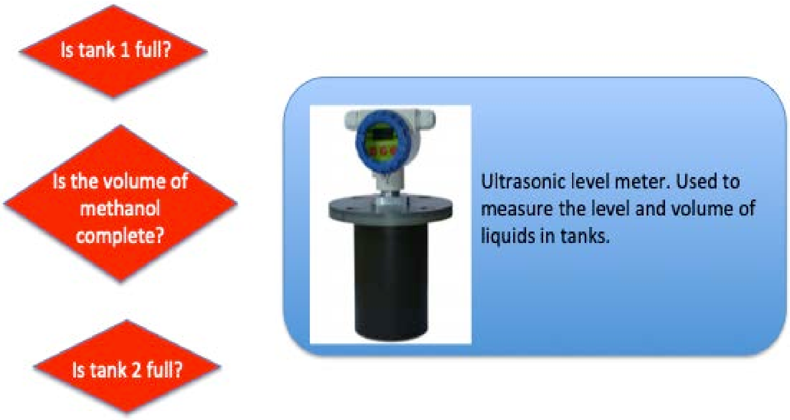


Figure 24 - Stage where valves are used.



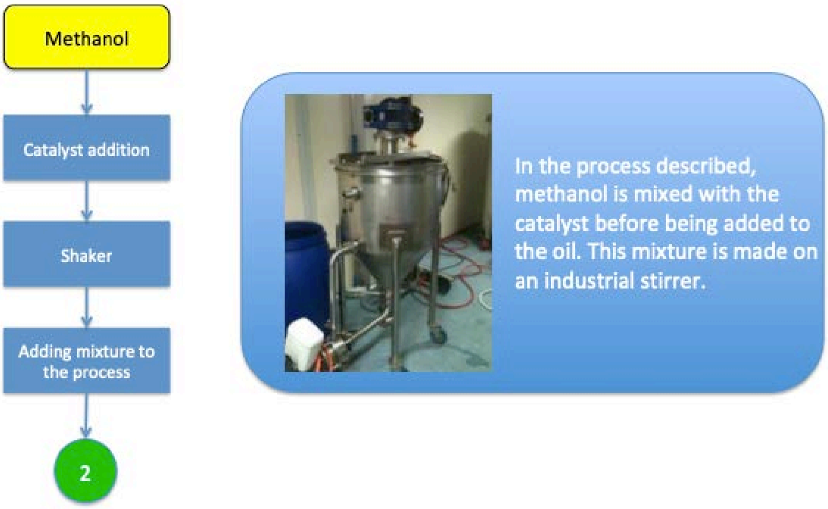
Temperature measurement is critical for various stages of the biodiesel manufacturing process. Digital thermometer with PLC communication protocol.

Figure 25 - Decision stages where thermometers are used to read temperatures.



Ultrasonic level meter. Used to measure the level and volume of liquids in tanks.

Figure 26 - Decision stage where level meters are used to read the volumes of tanks.



In the process described, methanol is mixed with the catalyst before being added to the oil. This mixture is made on an industrial stirrer.

Figure 27 - Ethanol Mixing Tank Operation Stage

8.4 Instrument diagram

The acronyms are: FAME (Fat Acid Methyl Ester); OH (Methanol), NaOH (basic catalyst); GLOL (Glycerol); WVO (Waste Vegetable Oil), crude vegetable oil and finally water. The tanks are numbered in the order of use: Tank 1: purification tank; Tank 2: reaction tank; Tank 3: filtration tank. Valves are symbolized by butterflies, a symbol commonly used in instrument diagrams to represent valves. The lines in the diagram have arrows that represent the direction of liquid travel within the plant. Inside the tanks 1 and 2 are the heating elements and in the tank 2 outside, you can see the methanol heat exchanger. The blue cylinders with black rods represent the hydraulic pumps, as shown in the figure below:

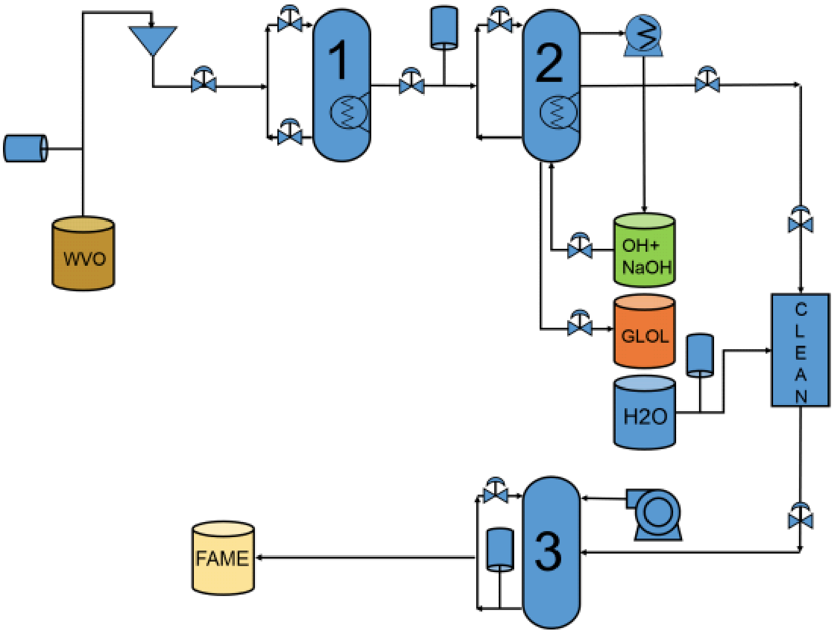


Figure 28 - Biodiesel plant Instrument Diagram.

8.5 Plant layout

Following the norms previously presented, the author also made a preliminary factory floor layout of the plant developed by KEMP.

The space is a rectangular room 5 meters long and 4 meters wide. In the background there is a platform where the three main tanks of the plant are supported. The crude vegetable oil is in a container on the floor of the room. Outside the room there is an environment where the biodiesel cleaning water is stored and this place is connected to the main room by means of a water pipe. The alcohol heat exchanger is attached to the wall behind the plant and finally the biodiesel produced is stored in a tank similar to the crude oil on the floor of the room. The layout is shown below.

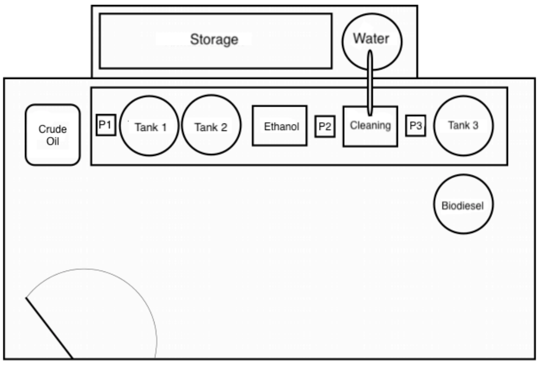


Figure 29 – Biodiesel Plant Layout

8.6 PLC Programming

In this session will be presented how the programming in Ladder language of the Programmable Logic Controller using the software. The session is subdivided into three subtopics:

1. Process simulators, where it will be explained how the temperature and volume variables of the plant were simulated.

2. Process control, which will show the Ladder code made to control the biodiesel plant.

3. Communication with SCADA, where it will be presented how the communication adjustments were made between these two parts of the process.

8.6.1 Variable Simulation

The core of Ladder language programming for the biodiesel plant was the simulation of analog variables. One of the project requirements was that the PLC did not have analog sensors in its composition, that is, the volume and temperature values would be simulated virtually inside the controller, not measured. For there is no physical plant involved in the process.

To fulfill the requirement, it was necessary to use different function blocks in the program, so that, when associated, they simulate volume and temperature values within the plant tanks. The variables were simulated individually, with no relationship between them. Each increasing volume, each varying temperature varies without requiring value dependence on another simulated system variable.

In the volume and temperature increase steps the Up counter block was used: CTU. The CTU block has an internal function which when activated by the PLC's virtual bus generates increasing values. These values are increased by one unit at each step of the PLC's internal clock starting at approximately -33000 to +33000 units. When the maximum value is reached, the counter returns to the initial value, -32767 and continues repeating the process in this loop, until the bus is turned off.

The figure below shows the CTU block and the virtual bus.

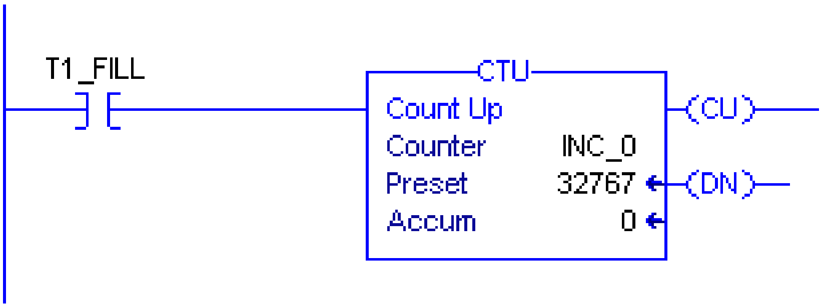


Figure 30 - CTU Function in LADDER Program

For decrementing functions the CTD function was used. The CTD function operates exactly the same as the CTU function, but decreasing the tag value. Upon reaching the minimum loop value: -32767, it reverses the number sign and continues until the bus is turned off.

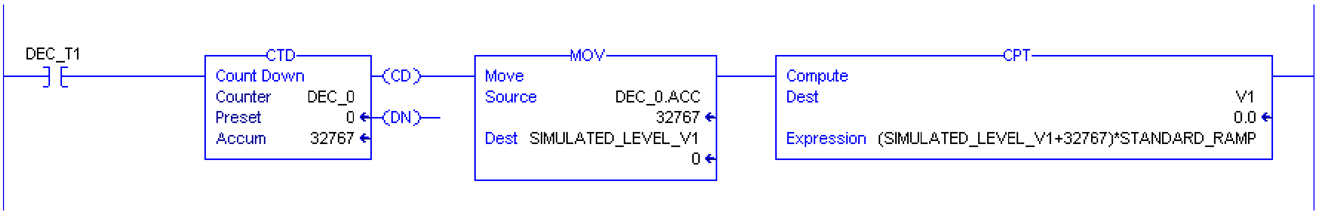


Figure 31 - CTD Function in LADDER Program

The CTU or CTD blocks, counter functions, assign the generated value to a tag associated with them. Since the internal variation of the counter functions does not represent actual volume or temperature values, the CALCULATE function is used to mathematically transform the tag value into representative values of simulated quantities. The CALCULATE function performs mathematical operations with the values of its inputs: IN1, IN2, IN3, etc., as shown in the figure below.

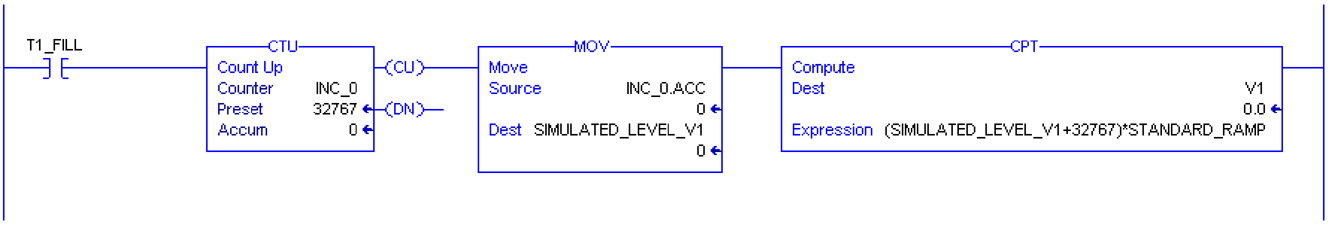


Figure 32 - CTU and CALCULATE Function in LADDER Program

Example: In the first tank, the cleaning tank, the volume of vegetable oil received is 200 liters. To simulate the volume ranging from 0 to 200 "liters", the value of +32767 was first added to the tag '# LEVEL SIMULAT', tag generated by the block INC. Thus, the smallest value of the tag goes from -32767 to 0. Consequently, its largest value is also changed to 65534. For the upper threshold to be 200 instead of 65534, it is necessary to create a linear function with known variation. .

The time variation of the counter block functions was obtained by measuring the total time of a function loop: the time required to reset the internal counter. The same loop time was used to create a function whose maximum value was 200, as shown in the figure below. In possession of both original and ideal functions, the ratio between their coefficients of variation was obtained. The result was 0.01526; this value and the coefficients of variation of the functions are shown in the graph below. This value was assigned to one of the CALCULATE function inputs, so it was possible to generate the output: '# V1' (Tank 1 volume) ranging from 0 to 200 liters, simulating a real behavior of volume variation function. The same procedure was used for temperature variables.

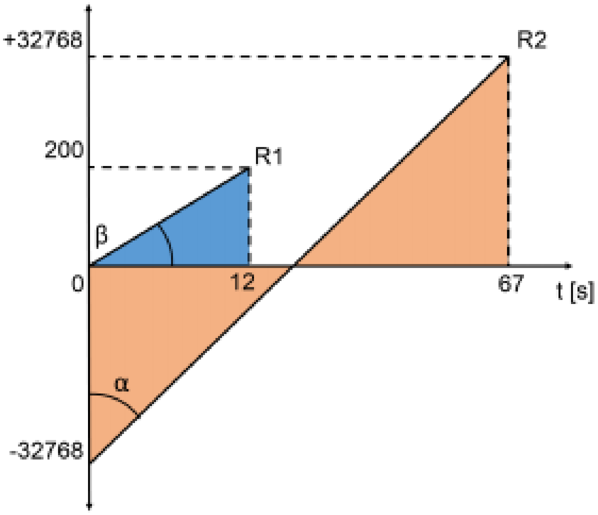


Figure 33 - CTU value change function by time

Mathematical division operations performed within the CALCULATE function generate real numbers as a result. Although the calculated values are mathematically correct, it is interesting to the user that the decimal part is deleted. When the decimal part is greater than 0.5 rounds up if the decimal part is less than 0.5 rounding down to the nearest integer.

SCADA system did not require much precision in its operation, since the objective is to perform a general simulation of the biodiesel production system, using 200 liter tanks. Decimal parts of numbers close to 200 make no difference in operation, representing a 10 (-3) scale error. To perform rounding, the CONV (conversion) function block was used.

CONV block transforms real-value inputs to integer set outputs. The function output tag is the tag sent to SCADA to represent tank volume or temperature values. The CONV function is shown below.

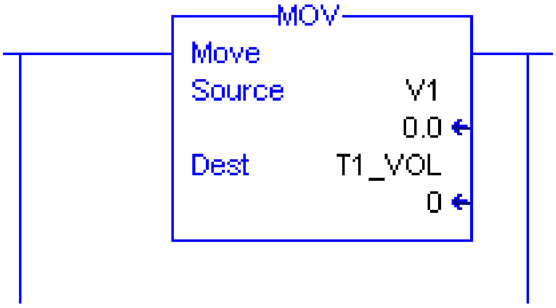


Figure 34 - CONV (conversion) Function

Among all the tanks of the biodiesel production plant, one stands out for its individuality, the ethanol tank. The alcohol tank is the only one in the plant that starts with non-zero internal volume; the initial volume of ethanol is 40 liters. The MOVE variable assigns the volume value to the tank as soon as the program is started. Therefore, there is no CTU block associated with any step involving the ethanol tank, only CTD. The following figures show the MOVE function assigning twice the initial reagent value in 40 liters, the CTD and CALCULATE function related to the volume decrease of this tank and the image of the alcohol tank in the supervisory.

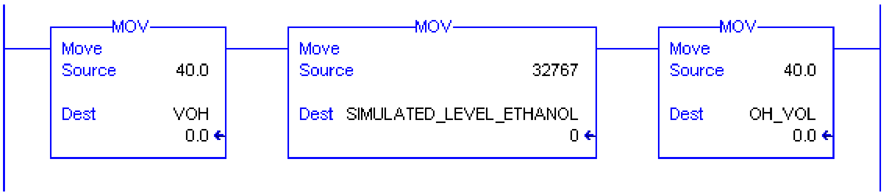


Figure 35 - MOVE Functions Regarding the Alcohol Tank

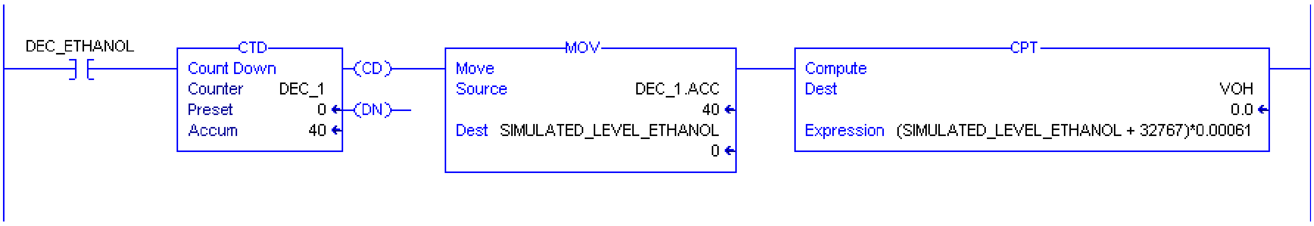


Figure 36 - Alcohol Tank DEC and CALCULATE Functions

8.6.2 Process control

At the beginning of the LADDER program, the initial values of the variables are declared in the system. These constants can be used in mathematical operations of the CALCULATE function, such as the constant: 0.01526. The minimum volume and temperature values (0.0 liters and 0 degrees, for example) are assigned by the MOVE function, which assigns values to an internal program constant, or tag, placed in its input.

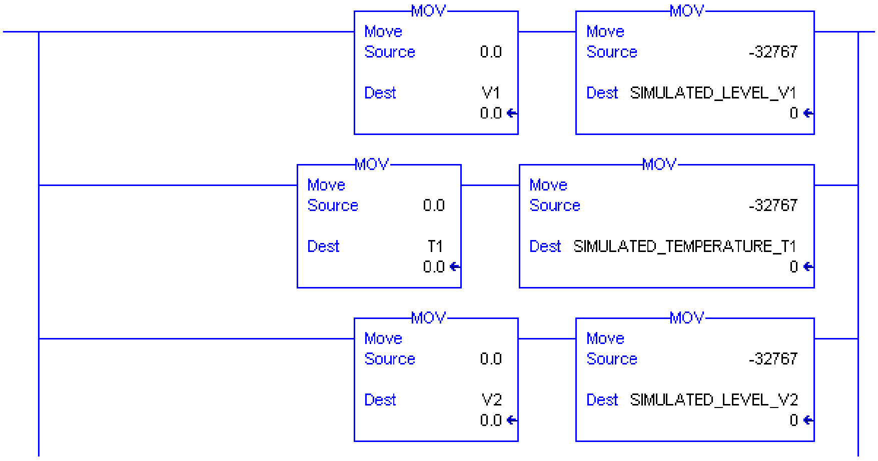


Figure 37 - MOVE Multiple Function Set

The steps of the LADDER logic are too fast for the user to observe and last about fractions of a second due to the PLC scan itself. As explained earlier, some steps that occur within the program simulate variables, but the steps where no variables are not simulated are very brief. Such steps were deliberately delayed for the user to better appreciate them. In order to generate delay, the TON (Generate on-delay) function block is used which works when powered by the PLC bus. It waits for a known time value and connects the next bus to it. In the case shown in the figure below, the step where the temperature of the reaction tank (tank 2) reaches 50∘C is delayed by ten seconds to allow the user to observe the event. If there was no delay the temperature would reach 50∘C and would instantly trigger the next function, which raises the temperature to 80∘C, and would continue the program execution. The 50∘C level would be imperceptible, since such a step is important because it is the reaction temperature of biodiesel.

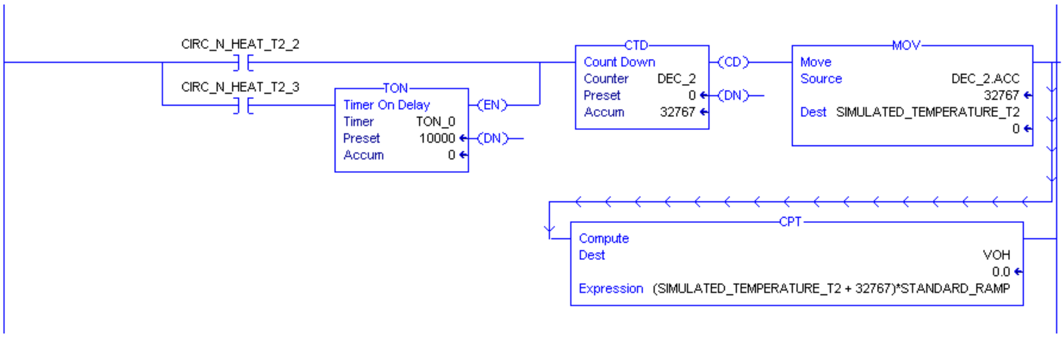


Figure 38 - TON function Generate on-delay

The biodiesel production flowchart was translated step by step into ladder logic each decision event was transformed into a ladder logic step.

8.6.3 Digital Actuators

Although the program consists of a biodiesel production plant simulator, the operating coils of each process electronic actuator were implemented in the code. This fact makes the programmed system can, in a real scenario, operate real actuators of a plant. This care was taken because the code can, in future works (not being the case of this one), be used in real situation of biodiesel production industry.

The coil is a digital element that only allows two states: on and off. There is no step in the biodiesel production process that requires an actuator to operate analogously, ie with various voltage levels at its input. Even the electric motors of the pumps are digitally operated, because their speeds are equal throughout the use of the plant. This means that once the voltage adjustment is required to achieve the desired speed, the engine can only be started and will operate at the desired speed, making it a digital type actuator.

Actuators are: hydraulic pumps for moving oil inside the plant; electric heaters; other actuators, such as the air compressor and the hot air blower in the third tank, and especially valves. To operate each actuator a logical coil operation is used as shown below.

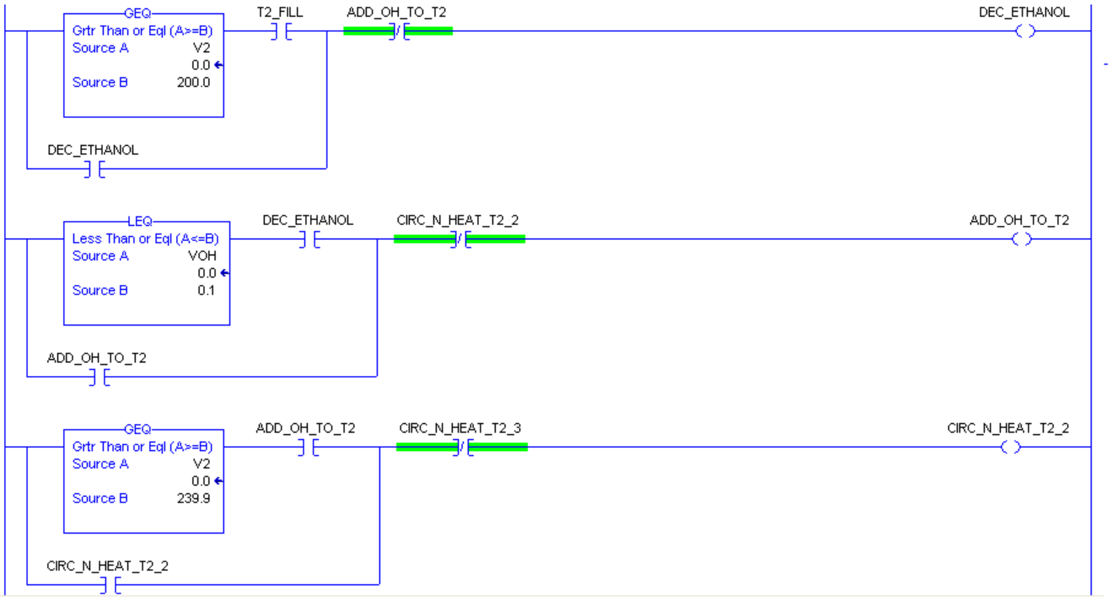


Figure 39 - Actuator Drive Coil Example

It is possible to observe that before the coil the conditions of use of the actuator are located. In the case of the example used, the conditions are: Fill tank 1, circulate and heat tank 1, fill tank 2 and empty tank 2.

9. Integration PLC and SCADA

There was no need to use a PLC physically composed of real hardware. For the control and simulation of the biodiesel production process, RSLogix Emulate 5000 was used, software that simulates a PLC without the physical hardware, making it possible to perform the control in very similar conditions that a real PLC would work.

In this project the name given to the simulated PLC was ME700_Thesis, and this module was created in slot 2 as shown in Figure 40.

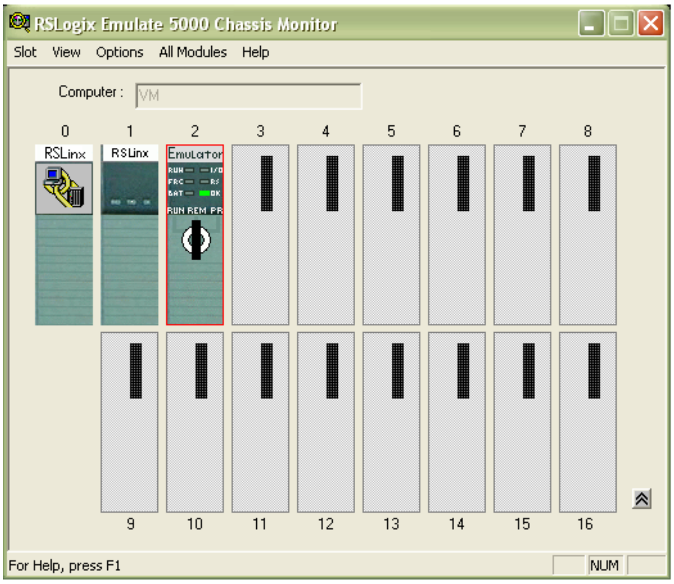
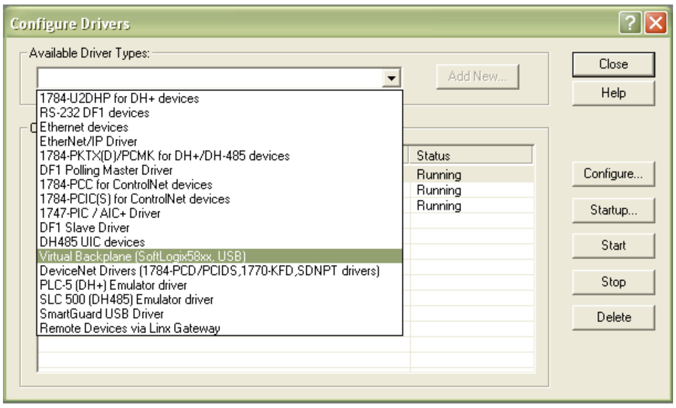


Figure 40 – RSLogix Emulate 5000 software main screen.

To integrate RSLogix 5000 (PLC) software with Factorytalk View SE (SCADA) on the Rockwell Automation platform, you must first access the RSLinx Classic Gateway software (responsible for integrating the Rockwell platform with automation devices through communication protocols), navigate to the Communications taskbar, and click Configure Drivers to create a Virtual Backplane (Softlogix58xx, USB) communication drive, which corresponds to the drive that communicates RSLogix Emulate 5000 with RSLogix 5000 software (which allows the development of PLC programming logic).



1784-U2DHP for DH+ devices
RS-232 DF1 devices
Ethernet devices
EtherNet/IP Driver
1784-PKTX(D)/PCMK for DH+/DH-485 devices
DF1 Polling Master Driver
1784-PCC for ControlNet devices
1784-PCIC(S) for ControlNet devices
1747-PIC / AIC+ Driver
DF1 Slave Driver
DH485 UIC devices
Virtual Backplane (SoftLogix58xx, USB)
DeviceNet Drivers (1784-PCD/PCIDS,1770-KFD,SDNPT drivers)
PLC-5 (DH+) Emulator driver
SLC 500 (DH485) Emulator driver
SmartGuard USB Driver
Remote Devices via Linx Gateway

Figure 41 - Screen containing the PLC simulator driver.

This is done by navigating to the RSWho-1 window, expanding node AB_VPB1, 1789-A17 / A Virtual Chassis to view the simulated PLC communication architecture. To perform simulated PLC OPC communication with other automation devices, simply right-click the object named ME700_Thesis (Simulated PLC) and then click Configure New DDE / OPC Topic.

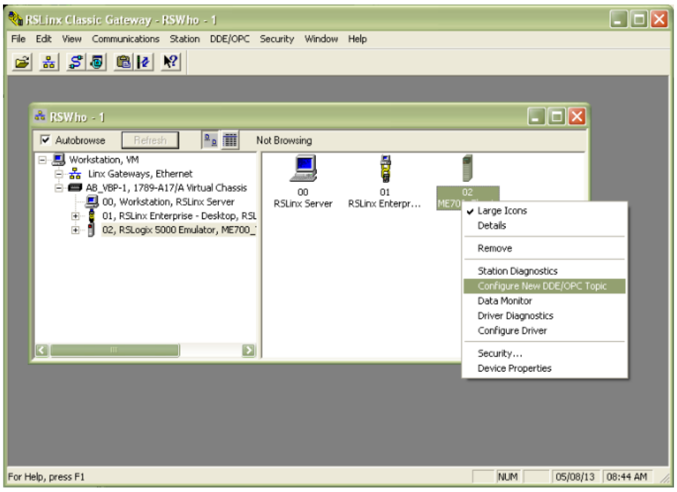


Figure 42 - Screen containing PLC simulator driver and DDE / OPC topic.

It is in this option that a DDE / OPC topic is created to perform the integration between the software (RSLogix 5000 and FactoryTalk View SE) using the OPC communication standard. A DDE / OPC topic was also created with the name ME700_Thesis in order to standardize the project.

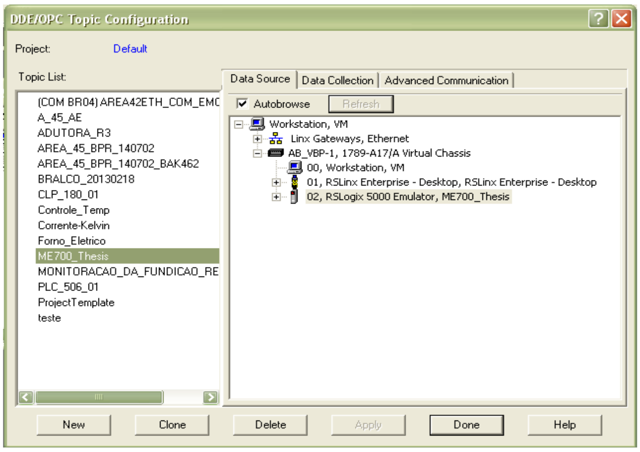


Figure 43 - Screen containing topic DDE / OPC.

The OPC communication protocol makes it possible to integrate the simulated biodiesel plant in real time with Rockwell Automation platform control and supervision software.

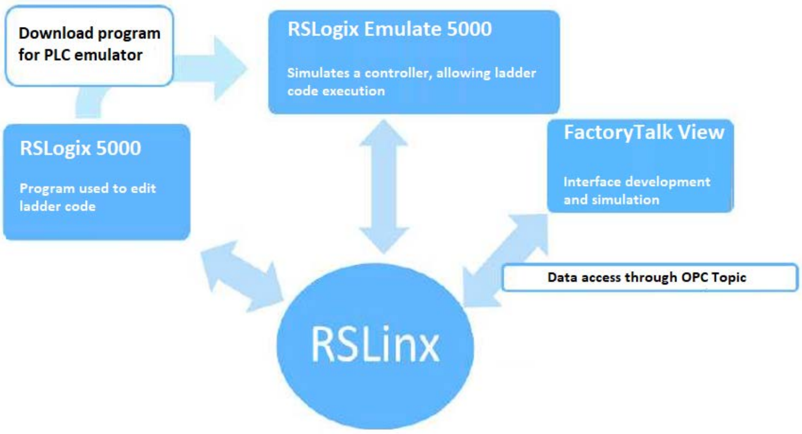


Figure 44 - Relationship between the software used.

10. Supervisory System Project

This chapter will cover the construction and use of the supervisory system designed for the biodiesel production plant. Initially an overview of the system with its tanks, valves and conductors will be shown to show the construction details.

Then the main decisions made for the supervisor to represent well and didactically the operation of the plant will be shown. Emphasis will be placed on the volume and temperature meters present in the plant and saved in a library created for future work.

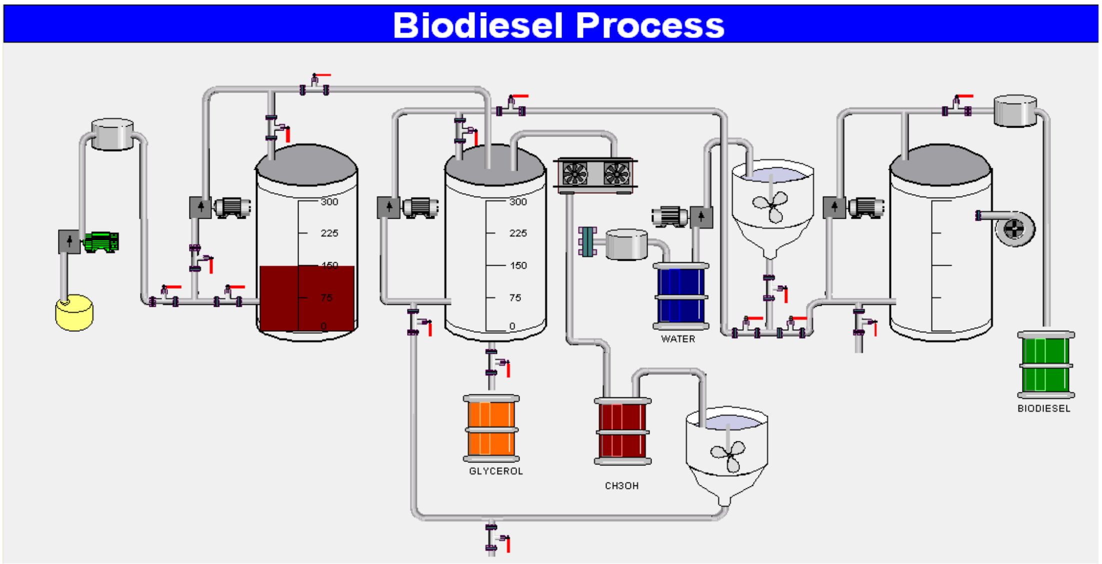


Figure 45 - Plant Overview

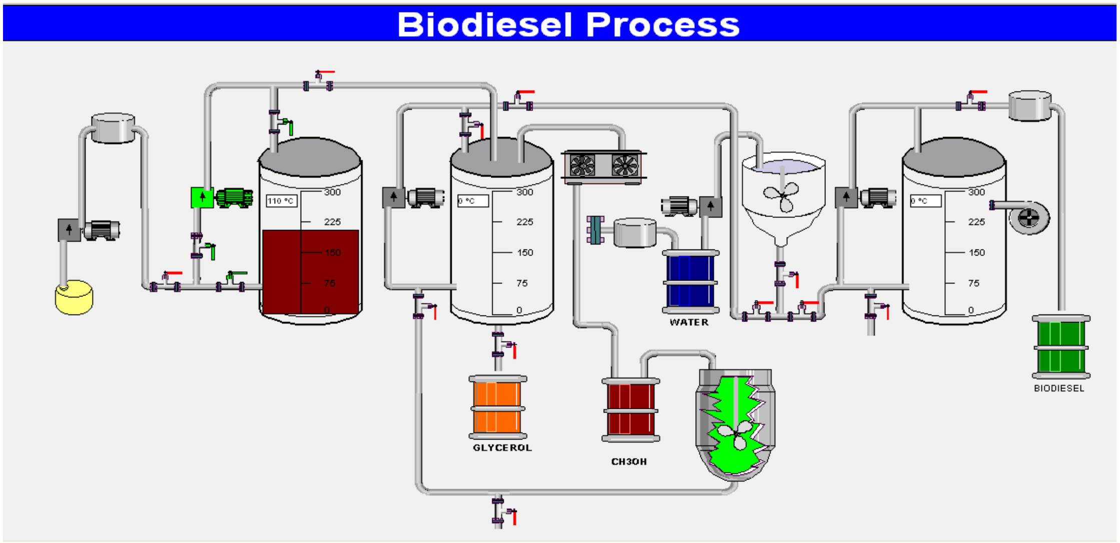


Figure 46 - Plant Overview

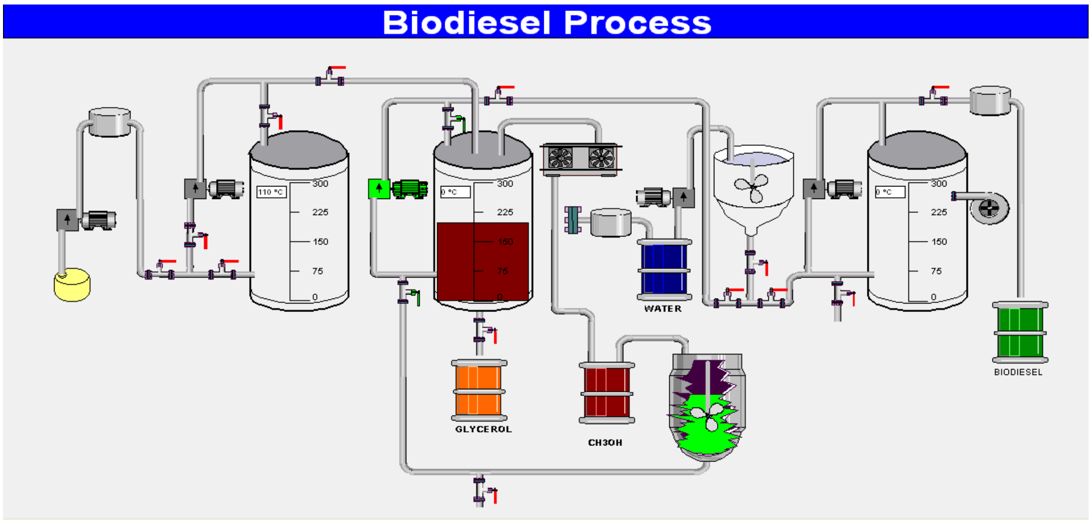


Figure 47 - Plant Overview

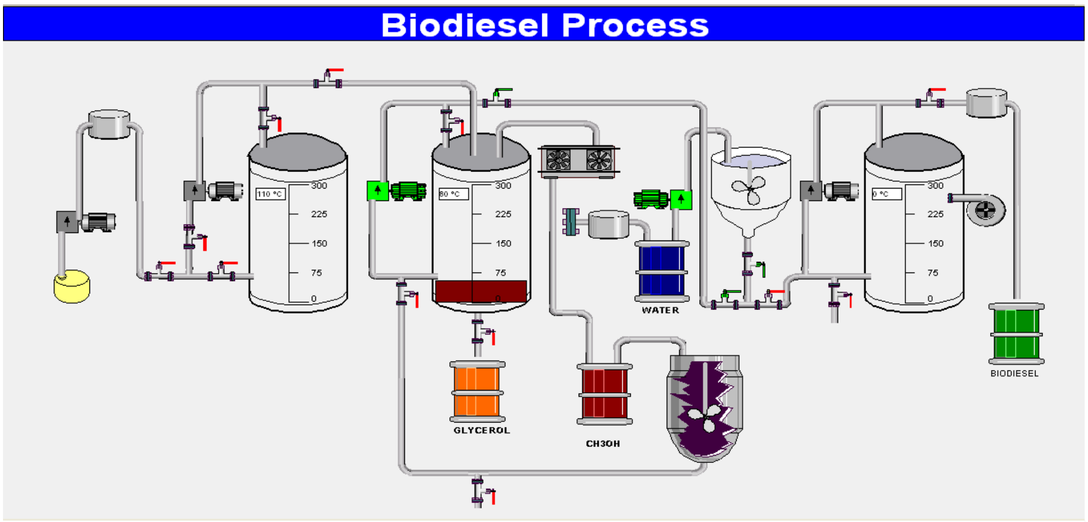


Figure 48 - Plant Overview

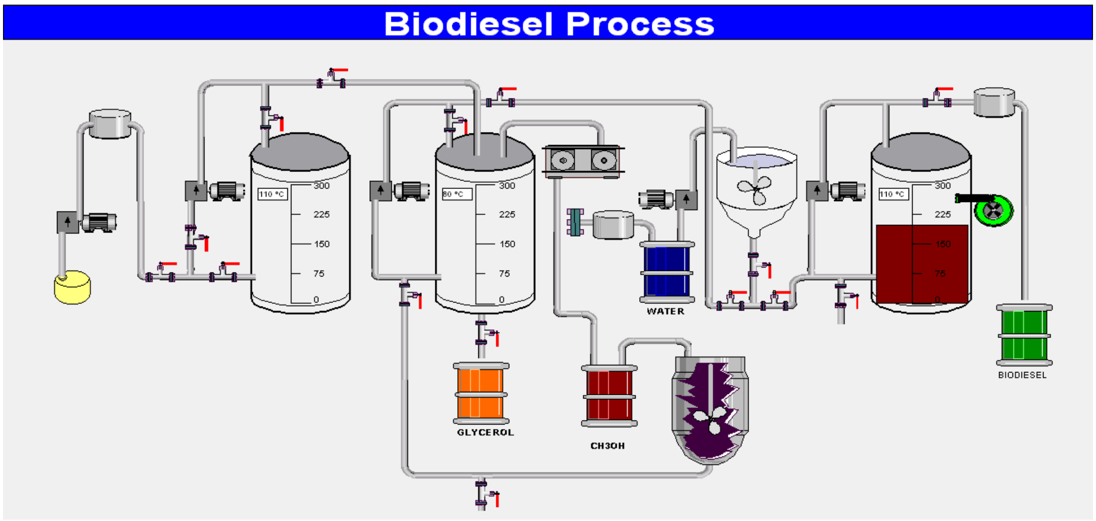
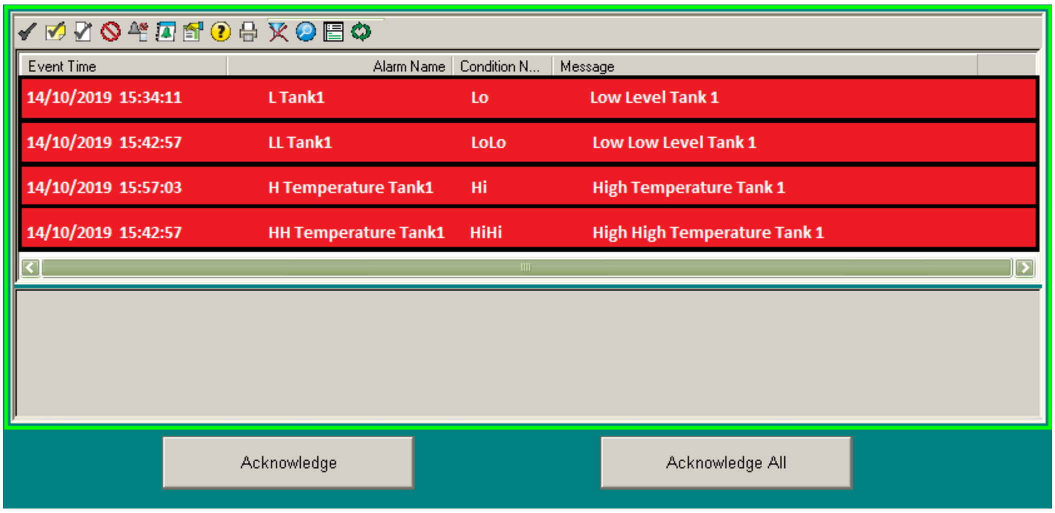


Figure 49 - Plant Overview

10.1 Alarms

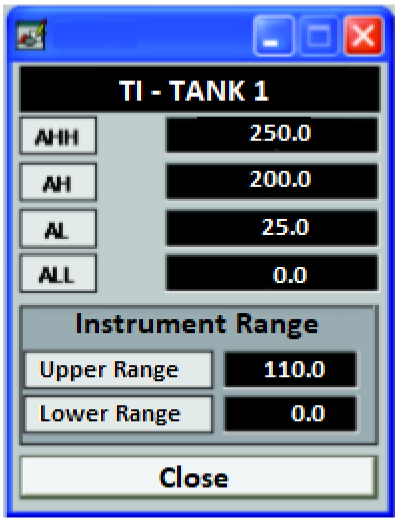
An alarm panel with temperature and volume alarms has been implemented for the supervisory to warn the user about abnormal behavior of these variables during operation. Alarms can be viewed on a screen where the user will have access to the history of alarms that may arise during the operation of the process. It is also on this screen that the user can, after identifying a particular alarm, click on the button “Acknowledge”. to allow the plant to start again, but this command should only be triggered when the cause of the alarm is identified and resolved, ie when the plant returns to normal operating conditions.



Event Time	Alarm Name	Condition N...	Message
14/10/2019 15:34:11	L Tank1	Lo	Low Level Tank 1
14/10/2019 15:42:57	LL Tank1	LoLo	Low Low Level Tank 1
14/10/2019 15:57:03	H Temperature Tank1	Hi	High Temperature Tank 1
14/10/2019 15:42:57	HH Temperature Tank1	HiHi	High High Temperature Tank 1

Figure 50 - Alarms

Each alarm is associated with an analog system variable, as shown in the alarm properties table below. In the images it is possible to see that the alarms inform when the temperature or volume go out of values or levels set by the user. The HiHi threshold, which refers to 'very high', when exceeded, triggers an alarm that informs the user of this information. LoLo, 'too low' reports values too low of the associated variable. For intermediate value levels Lo and Hi options can be implemented. Alarm severity can also be adjusted: high, medium or low. Severity is associated with the color the alarm appears in the alarm board.



TI - TANK 1

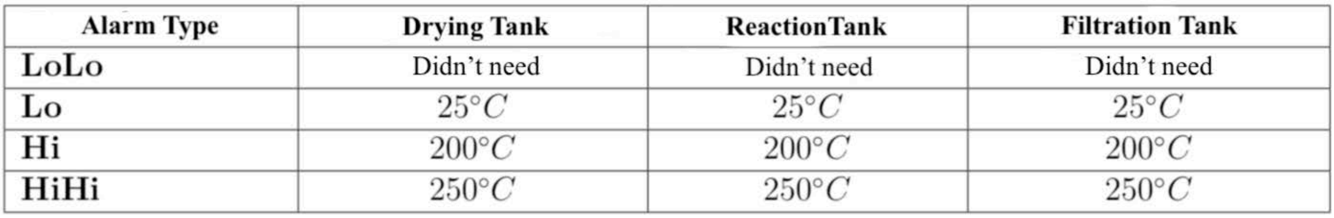
AHH	250.0
AH	200.0
AL	25.0
ALL	0.0

Instrument Range

Upper Range	110.0
Lower Range	0.0

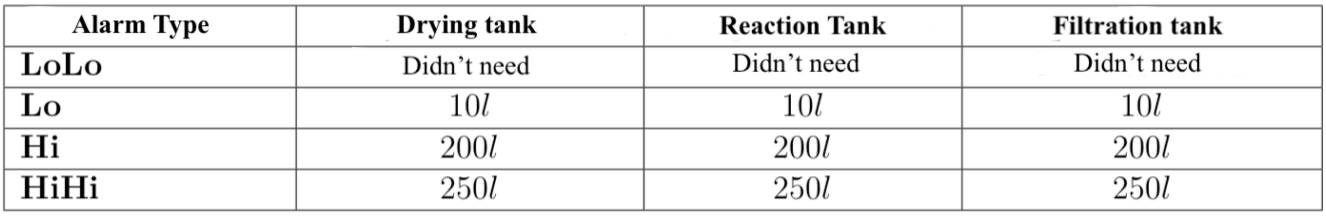
Figure 51 - Alarms

The alarms entered into the system were for temperature and volume values of the three tanks, drying, reaction are listed in the following table in two tables, one for temperature alarms and one for volume alarms.



Alarm Type	Drying Tank	ReactionTank	Filtration Tank
LoLo	Didn't need	Didn't need	Didn't need
Lo	$25^\circ C$	$25^\circ C$	$25^\circ C$
Hi	$200^\circ C$	$200^\circ C$	$200^\circ C$
HiHi	$250^\circ C$	$250^\circ C$	$250^\circ C$

Table 1 - System Temperature Alarm Values



Alarm Type	Drying tank	Reaction Tank	Filtration tank
LoLo	Didn't need	Didn't need	Didn't need
Lo	$10l$	$10l$	$10l$
Hi	$200l$	$200l$	$200l$
HiHi	$250l$	$250l$	$250l$

Table 2 - System Volume Alarm Values

The temperature and volume alarms modulus are simulated, as the Hi alarm for both volume and temperature alarms has 200 units. The values are close to the values measured in real situation. In fact the tanks of the studied plant have a volume of 200 liters and, in fact, a high temperature, which has alarm value, in the case of vegetable oil being transformed into biodiesel is 200 °C.

In the case of the second tank, the transesterification reaction tank, more precisely, in the event of excess methanol condensation, there is increased pressure in this tank. A pressure alarm would be interesting in a possible real simulate plant design. But since the pressure variable was not simulated it was not possible to create such an alarm.

Chapter 4

11. Hypotesis

The book does not say how much time is spent on the labor process and the quality values of the biodiesel produced. It just explains that the manual process, because it does not have an accurate measurement of inputs and controls, often produces low quality biodiesel. In this work, it was not possible to obtain these quantitative data. But of course automation can improve the process qualitatively since automated plants offer greater operational safety, less wear and tear on industrial equipment, better product quality by operating around desired operating values, shorter production time as this is one automated system that does not need human interference in the process (manually open and close valve, manually turn on / off equipment).

12. Results

The project developed in this work presents a proposal of supervisory system and control of the chemical process of biodiesel production. As has been shown, small-scale fuel production plants are a response to the current onset of declining fossil fuel extraction for automotive or home heating. Small-scale production plants are much less expensive and simpler to operate than their large-scale counterparts, which perform the same chemical process. But the quality of the fuel produced by the smaller type of plant is mostly questionable, mainly due to the low level of process control. Therefore, control and automation system design proposals are required for fine control of such equipment. The algorithm and the supervisory system developed in this work present a solution to the existing quality problem. Because the program controls the main parameters required for the production of biodiesel and presents to the user, through graphs and digital dials, the process details as well as temperature and volume information in each of the three stages of fuel production: purification, reaction and drying.

The algorithm developed in ladder language controls all actuators used in the chemical process including the three hydraulic oil movement pumps within the system, all sixteen valves in the reagent transport tubes, the electric heaters in the tanks, the air compressor, the hot air blower and the bubble maker for cleaning. The control allows the PLC to operate the actuators, send and receive information to the plant and present to the supervisory system the temperature data of the tank volume. In addition to controlling the actuators the code goes through the fuel production steps in the correct order: crude vegetable oil uptake, purification, reaction, cleaning and drying the final product. Allowing production to complete correctly and at the end of a batch the process can be repeated perfectly. The repeatability of control processes is a feature of the ladder language useful for situations such as biodiesel production.

As the project developed in the present work simulates biodiesel production, the data of variables, volume and temperature were emulated within the ladder code. The simulation allowed validating the code without the need for real bench application. The validation of the simulated results was made by comparing with true data present in the book. The variables were simulated entirely using pre-existing functions in the RSLogix 5000 portal, the software where the algorithm was developed. No need to use other software in parallel facilitating the complete development of the algorithm avoiding c ommunication errors or incompatibility.

The supervisory system developed presented an ideal interface for the sampling of data generated by the simulation, for the user. The result was a clear and efficient means of presenting system state information at all times of operation. Containing screens from each of the three tanks, easy-to-view bright colors, alarms with real alert levels, animation of all reagent movement in the system, which allowed the user to know what happens in real time in the plant.
In addition to generating useful graphs with tank temperature and volume information for each batch performed.

Saving labour time: In the manual process, the operator is essential in all stages of the process to control the flow and equipment. At least 8 hours is needed to produce Biodiesel. In the automated plant, the operator just needs to fill the tank with WVO and mix the reagent.

Quality: Manual process may produce poor quality biodiesel. Control temperature, reagent mix and filtration are essential steps to get good biodiesel. Failure in one of these steps can produce biodiesel out of international specifications with excess water, high alcohol and glycerin content. These problems could cause severe damage to engines such as corrosion and filter and nozzle clogging.

The project developed in this work included the vast majority of elements of a complete automation control and supervision system of a small-scale biodiesel production plant. It would be of great contribution to the improvement and assembling of the developed programs that the algorithm was employed in bench situation validating for situations of real use of biodiesel production.

Another contribution would be the addition of two transesterification tanks thus contemplating the most current designs of plants that have two reaction tanks. It is also useful to insert in both ladder and supervisory code two cleaning tanks, one for acid cleaning and one for basic cleaning, thus neutralizing the two types of impurities generated in the fuel production.

13. Conclusion

This work is justified in the goal of partially reducing the inefficiencies in the operation of manual plants. Manual biodiesel plants can produce useful fuel, but the quality of the final product varies greatly from batch to batch. By applying automation design with actuators, sensors and controllers it is possible to increase the quality of operation and consequently the quality of the final product.

The supervisory system developed presented an ideal interface for sampling the data generated by the simulation, for the user. The result was a clear and efficient means of presenting system state information at all times of operation.

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