PLC CONTROL OF THREE PHASE INDUCED MOTORS

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ANDI SHEHAJ

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"PLC control of three phase induced motors"** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master.

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ABSTRACT

PLC CONTROL OF THREE PHASE INDUCED MOTOR

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Remote control applications arevery popular in today's industries and even for a long time, engineers have been focused on improving industrial output. Inverter fed induction drive systems are one of the most prevalent applications that require remote control and monitoring. The speed of the motor, as well as the forward and backward turning directions of the motor are all controlled by various types of controllers in the drive system.A Programmable Logic Controller (PLC) can be used to implement this strategy also RS485module will be used in order to achieve the remote control system.Technically, a programmable logic controller is a process control device utilized mostly in the automation industry.“How does it affect in the progression of the work, electricity consumption and in the life time of the motor?” The aim of this thesis is creating a PLC with it is own softwaretogether with the VFD (Variable Frequency Drive) in order to completely automates the work of different motors at the same time by taking the information from different sensors and sending the adapted frequency to the motor, in order to have a quick and easy monitoring, less electricity consumption and increasing the life time of the motor.

Keywords*: remote control, automation, PLC, inverter (VFD), induction motor.

ABSTRAKT

KONTROLLI I MOTORAVE TRE FAZORE TE INDUKTUAR ME ANE TE PLC

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Supervizor: Assoc.Prof.Dr. Carlo Ciulla

Aplikimet e kontrollit ne distancë janë shumë të njohura në industrinë e sotme dhe madje për një kohë të gjatë, inxhinierët janë fokusuar tepër në përmirësimin e prodhimit industrial. Sistemet e drejtimit me induksion të ushqyer me inverter janë një nga aplikacionet më të përhapura që kërkojnë kontroll dhe monitorim në distancë. Shpejtësia e motorit, si dhe drejtimet e rrotullimit përpara dhe gjithashtu në të kundërt të motorit kontrollohen të gjitha nga lloje të ndryshme kontrolluesish në sistemin e lëvizjes. Një kontrollues logjik i programueshëm (PLC) mund të përdoret për të zbatuar këtë strategji gjithashtu do të përdoret moduli RS485 për të arritur sistemin e kontrollit ne distancë. Teknikisht, një kontrollues logjik i programueshëm është një pajisje e cila përdoret kryesisht në industrinë e automatizimit. "Si ndikon në ecurinë e punës, konsumin e energjisë elektrike dhe në jetëgjatësinë e motorit?" Qëllimi i kësaj teze është krijimi i një PLC me softuerin perkatës ku së bashku me VFD (i quajtur ndryshe Inverter) të automatizojë plotësisht punën e motorëve të ndryshëm në të njëjtën kohë duke marrë informacionin nga sensorë të ndryshëm dhe duke dërguar frekuencën e përshtatur motorit, për të patur një monitorim të shpejtë dhe të lehtë, më pak konsum energjisë elektrike dhe rritje të jetëgjatësisë së motorit pasi shmangim lëvizjet e forta dhe boshe te motorit.

Fjalët kyce* : kontrolli ne distancë, automatizimi,PLC, Inverter, motor i induktuar

Dedicated to my friends and family!

ACKNOWLEDGEMENT

I would like to express my thanks to my supervisor for the help that he gave me to write this thesis on time and for all of his advices, encouragement, motivation, corrections and support during all the stages of my thesis. I sincerely appreciate the time and effort he has spent to improve my experience during my graduate years.

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FEASIBILITY

The aim of this thesis is theautomationof the industrial machinery.Industrial production has been the focus of engineers for a long time now, because is a field that requires technology interventions in order to simplify the process. Simple and effective production management is made possible by checking and monitoring at each stage of the manufacturing process.This field has a wide range of uses but I have chosen the control of 3 phase induced motor with inverter via PLC.

In order to control it automatically without the presence of a person on the machinery (controlling it remotely)a PLC will be built. The main component for building the PLC is the 8-bitmicroprocessor “ATmega8” with 28-lead PDIP and with 23 programmable I/O lines. The working voltage is 4.5 - 5.5 V and speed grades up to 16 MHz it will be programmed by C++ language. The PLC takes information from the sensors and gives the response to the inverter in order to adjust the proper frequency to the motor. All the system can be monitored via PC with its own software by connecting the PLC and the PC via a RS485 module.

The motors will run automatically and also with the proper speed. It will not work anymore with that hard start and in the maximum speed but the speed will be dynamic and will change depending on the information given to PLC by the sensors which will be translated to the frequency given to the motor.

This technique is much more efficient than non-automated because is not necessary to be there on the company in order to run the motor or to check if it has any malfunction or not. It will have less electricity consumption and will increase the lifetime of the motor.

CHAPTER 1

INTRODUCTION

Most of the industrial companies nowadays have covered areas extending hundreds of kilometers of land, and even units might be located as far as separate cities. Checking and monitoring at each stage of the manufacturing process allows for simple and reliable production management.[1] It has always been critical to be able to handle such remote devices without the presence of any supervisory personnel on the premises. This simply increase the overall cost of the process control and the human negligence error would also be increased but nowadays, PLC automation is being used to reduce manufacturing costs while simultaneously improving process quality and dependability. Only because of advancements in automation technologies industries are growing exponentially. Due to the rise of businesses, automation in plants has become essential for industrial businesses' survival and even manual controls are being phased out.[2] The aim of the paper is automation control of the induced motor, which is taking a huge part in industries, , by using Programmable Logic Controller known as PLC and Variable Frequency Driver known as VFD. Is preferred to use VFD because of its advantages in energy consumptions, reduces Peak Energy Demand, which decreases power when it isn't needed, has a fully adjustable speed, regulated starting, stopping, and accelerating, dynamic torque control, and gentle motion for elevators.In general, because of environmental and manufacturing factors, VFDs are essential since many induction motor applications don’t require the very same speed.[3]The shaft's RPM should be modified as the load changes.[3] In 2015 S.R.Venupriya made a research for the controlling of the 3 phase induce motor and the inverter and he reached in conclusion that it can be easily controlled and fully automate the process. [4]

Muhammad Awaisin his research shows that the best way to control a induced motor is PLC. Adding a PLC to the excising system will increase the accuracy significantly and he reached in conclusion that the efficiency is increased by 10 to 12 %. [1]

They have built VSI hardware in order to run the induced motor in the open loop and the speed was varied because of the change of the VSI, also tried to reduce the harmonics from the rotor side. [2]

1.1. Speed Control

Both the Stator and Rotor sides influence the induction motor's speed. The speed control on stator-side of a three-phase induction motor is further characterized as:

1.1.1. Voltage control method

The square of the supply voltage affects directly to the torque, while slip against supply voltage at maximum torque is independent, suggesting that reducing the supply voltage reduces the produced torque.[5]As a bonus, with the same load torque, the slip increases as the voltage drops, and the speed decreases as well.[6]It is rarely used even though this is the best and easiest method, for a little change in speedis needed a large change in supply voltage. Moreover, the supply voltage change will result in a corresponding change in flux density, which can confuse the motor's magnetic conditions. [7]

1.1.2. Frequency control method

According to this approach, the speed of induction may be varied by modifying the stator frequency. In order to lessen the mother's pace, the mother's frequency must be adjusted. The flux must increase if the frequency falls while the voltage remains constant. Because of this drawback, this method is not often used.[5]

1.1.3. Pole changing method

Because of the easy modification of any number of stator poles, this technology is commonly utilized for squirrel cage induction motors.[8]Many independent stator windings wrapped for different number of poles in similar slots change the stator poles.For example, below it isshown the synchronous speed with the supply frequency 70 Hz and the number of poles four and six:[9]

Ns (Synchronous speed) for P equal to 4, Ns = 120*70/4 = 2100 RPM

Ns (Synchronous speed) for P equal to 6, Ns = 120*70/6 = 1400 RPM

1.1.4. V/f method

Voltage over frequency method is the most commonly used about managing the speed of the induction motors. 'V' represents the voltage and 'f' represents the frequency in speed change operations.[10]Variations in frequency caused by an inverter's supply voltage cause a change in the speed of a motor. This technique is more efficient in terms of performance.[11]As a result, a large percentage of AC speed drives adopt a constant V/f technique for speed control. This technique allows for a wide range of speed control and "smooth start" characteristics.[12]

The control of speed regarding three phase induction motor from rotor side is further classified as:

1.1.5. The control of Rotor Rheostat

This approach is similar to how the rotor rheostat of a DC shunt motor is regulated. This control isused just on slip ring motors since squirrel cage motors do not need and do not permit the placement of external resistance in the rotor.[13]

1.1.6. Cascade Operation

This cascaded motor speed is in charge of the system for three phase induction motors connects two three-phase motors which will share the same shaft. The motors are divided according to importance one will be primary motor and the other one will be auxiliary one. The supplemental motor gets its slip frequency from the primary motor's slip ring, while on the other hand the primary motor's stator gets a three-phase supply.[14]

Four distinct speeds may be obtained using this method: [6]

1. only primary motor works, speed formula is $Ns_1 = 120f / P_1$
2. only supplementary motor works, formula of the speed is $Ns_2 = 120f / P_2$
3. if constant cascading is performed, the set's speed= $N = 120f / (P_1 + P_2)$
4. if differential cascading is performed, speed of the set = $N = 120f (P_1 - P_2)$

1.1.7. Injecting EMF in Rotor Circuit

A fraction of the power is lost, like I2R losses in behalf ofthe speed of a 3(three)-phase induction motor is changed by adding resistance to the rotor circuit. [6]As a result, this form of speed regulation has an impact on a three-phase induction motor effectiveness. This slip fault may be recovered and utilized to increase the three-phase induction motor's overall efficiency. [15]The slip power recovery strategy is achieved by connecting an alternative source of slip frequency EMF to the rotor circuit.[16]

CHAPTER 2

MATERIALS

Main components that are needed for this project are Induced Motor, VFD (Variable Frequency Driver) and PLC (Programmable Logic Controller). In the picture below is shown the total scheme of the project

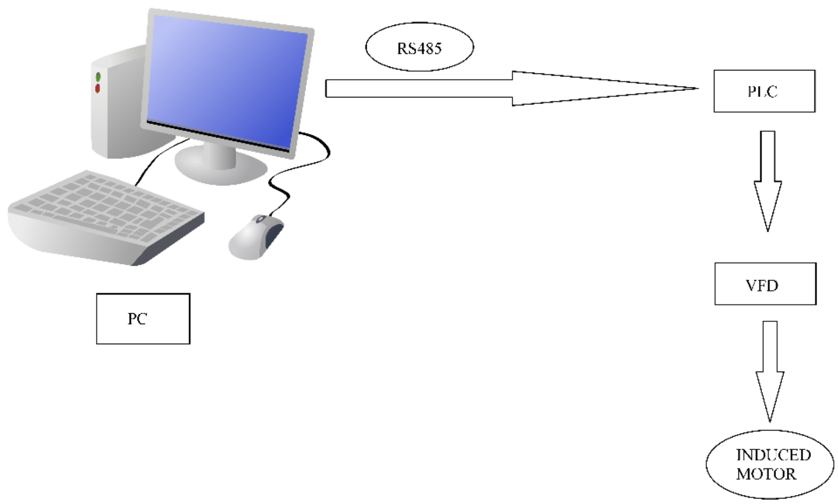


Figure 1. Circuit diagram

2.1. Induced motor

A spinning transformer type is the induction motor. A motor is machine that turns electrical energy into a mechanical one.[17]. The induction motor components are the stator and rotor. The stator is powered by alternating current to create magnetic flux in the rotor that results in the production of EMF.[18]. The motor moves because of the interactivity between the magnetic fluxes created by the EMF and by the three-phase supply.[19]It's also a very durable tool that requires very little care. It is also the most efficient and cost-effective motor available. The most frequently used as industrial drives are three-phase squirrel-cage motors because they are self-starting, steady, and cheap. Mono-phase motors are mostly used in low-load applications such as fans, shaker and other equipment used in the house.[20]What have always been used in applications that require fixed-speed, are induction motors that nowadays are being used much more in variable-speed applications. In order to put it in work it is used a variable-frequency driver. In variable-torque centrifugal fans, water pumps, compressor load and more and more applications VFDs provide existing and future induction motors significant energy savings opportunities. In fixed-speed and variable-frequency driving applications, are commonly used squirrel cage induction motors.The formula which calculates the speed of an induction motor is the formula **120f/p**.[19]

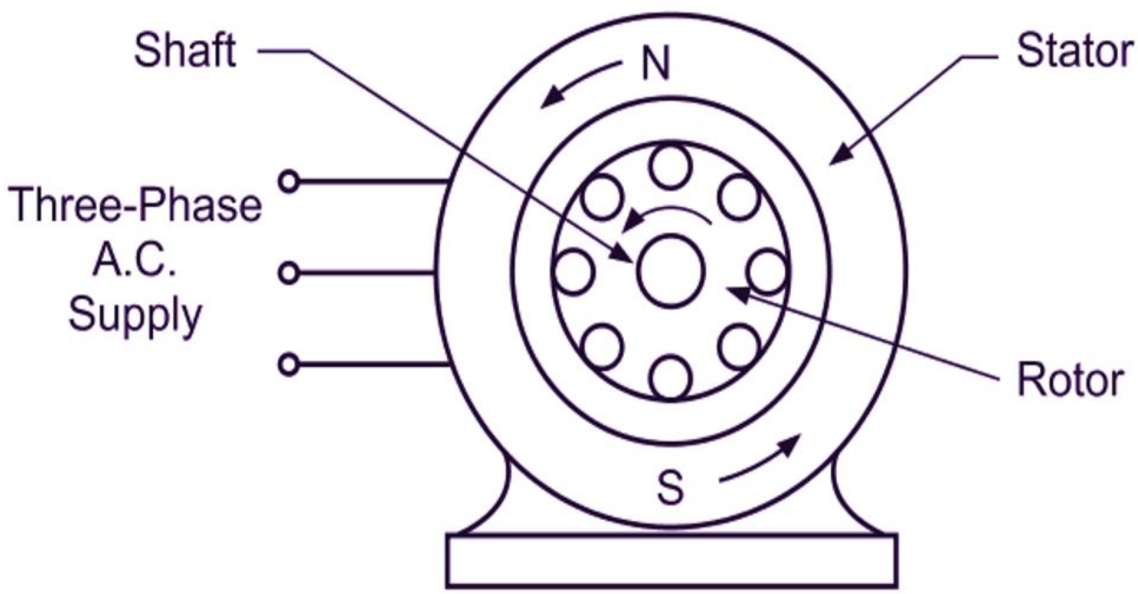


FIGURE 2.3 Phase Induced Motor*[21]*

2.2. Variable Frequency Diver (VFD)

A motor controller that regulates the voltage and frequency of the power supply, to a motor which is electric, is named variable frequency drive (VFD).[22]The VFD can also regulate the motor's speed during the start and the stop. VFD is known also as Variable Speed Drive, Adjustable Frequency Drive.[23] VFDs are used to drive variable-speed AC motors or to offer a smooth start by ramping up the speed gradually, which increase the life time of the motor also. The speed is controlled by modifying the frequency, which alters the RPM of the motor.The VFD's initial step is the converter, second one is the filtering stage (or DC Bus), and last but not least the inverter part.[24]It can work by altering the voltages twiceinto the circuit. The three-phase alternating current voltage is first turned to direct current (DC) using a diode. In the next step, all the noises in the DC voltage are filtered with the help of a capacitor filter.After that, DC voltage is changed to AC voltage using transistors. These are switches that allow you to control the voltage by modifying the switching angle. All of these steps are achieved by keeping the frequency stable at the proper levels. The speed formula is 120f/p. According to itthe motor's speed is directly proportionate to the frequency. The target value is calculated using a frequency calculation based on the required speed.[25]

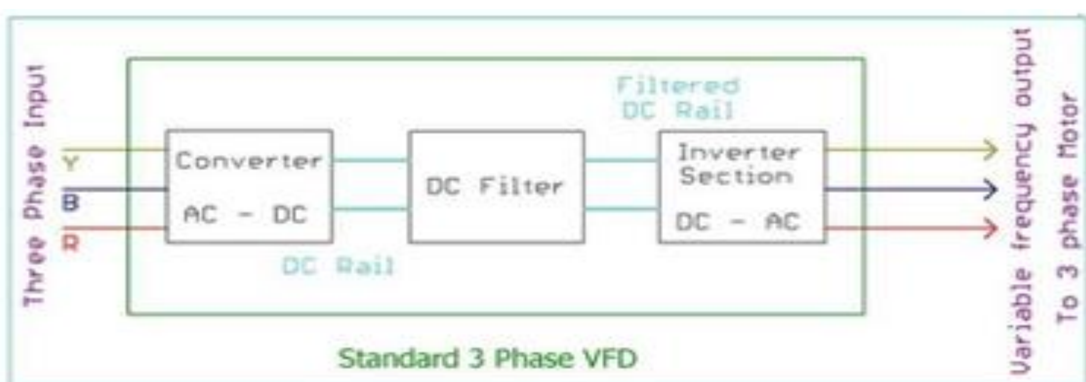


Figure 3. Variable Frequency Driver (VFD)*[26]*

2.3. Programmable Logic Controller

A programmable logic controller (PLC is a minor data processor which includes inputs and outputs that can take data and give operating instructions. The main function of a PLC is controlling the system's functions by using the internal principle which has been programmed into the processor.[27]All around the world PLCs is used to automate most of the important tasks. PLCs have replaced traditional hard-wired relays, timers, and other industrial components. A PLC's outputs may control many devices, including as motors, lights, solenoid valves, switchgear, safety shut-offs, etc .[28]In industrial applications are used PLC programs, which are a set of textual or diagram instructions. Specialized PLC programming software is included with a specific product's hardware which permits users to use and create user application code in the program that is downloaded to the PLC hardware. After downloading this program and importing to the PLC, set the PLC in "Run" mode and it will work in parallel with the codes or instruction of the program that it has.[29]

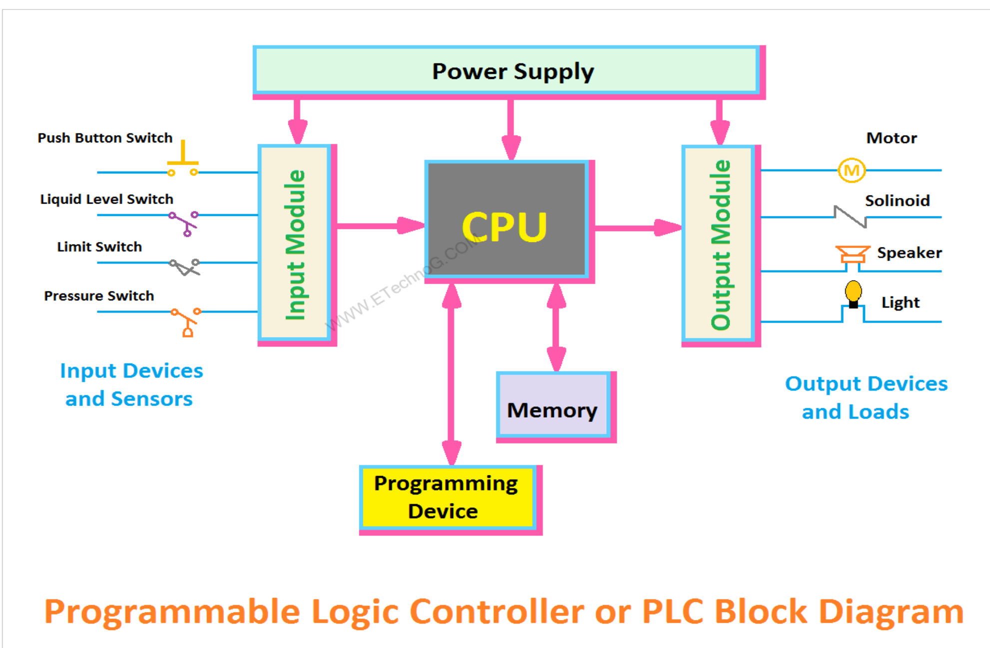


Figure 4.PLC Block Diagram *[30]*

The PLC's CPU executes two distinct programs:[31]

1. The Operating Program

The OS (operating system) arranges all of the CPU's functions, activities, and sequences which are not related to a control job. Among the operating system duties are:

- Update and exportthe process image tables of input and outputs
- Handling a warm restart
- Running the user software
- Detecting and asking to interrupt the program
- Dealing with the memory regions
- Communicating with programmable equipment

2. The User Program

The user system isa set of duties that collaborate with each other to perfume an automated task.This must be developed by the users and downloaded to the PLC's CPU.Among the users system duties are:[32]

- Reading and assessing all input signals which can be binary and analog
- Specifying output signals for all binary and analog output signals
- Interrupting the program and managing errors
- Setting up all of the requirements for commencing the given job

Some companies utilize programming languages that are comparable to others. PLC commonly used programming languages are grouped into two groups mentioned below, each of which has several kinds:

1. Textual Language

- Instructions List (IL)

- Structured Text (ST)

2. Graphical language

- Ladder Diagrams (LD)
- Function Block Diagram (FBD)
- Sequential Function Chart (SFC)

2.4. 16x2 LCD

The 16x 2 LCD are widely used in embedded system where some of the data needs to be shown on the display. The "16" stands for the number of pins and the "2" for the number rows. The operating voltage of the display is from 4.7 – 5.3 V and the current consumption is up to 1 mA without using the backlight.

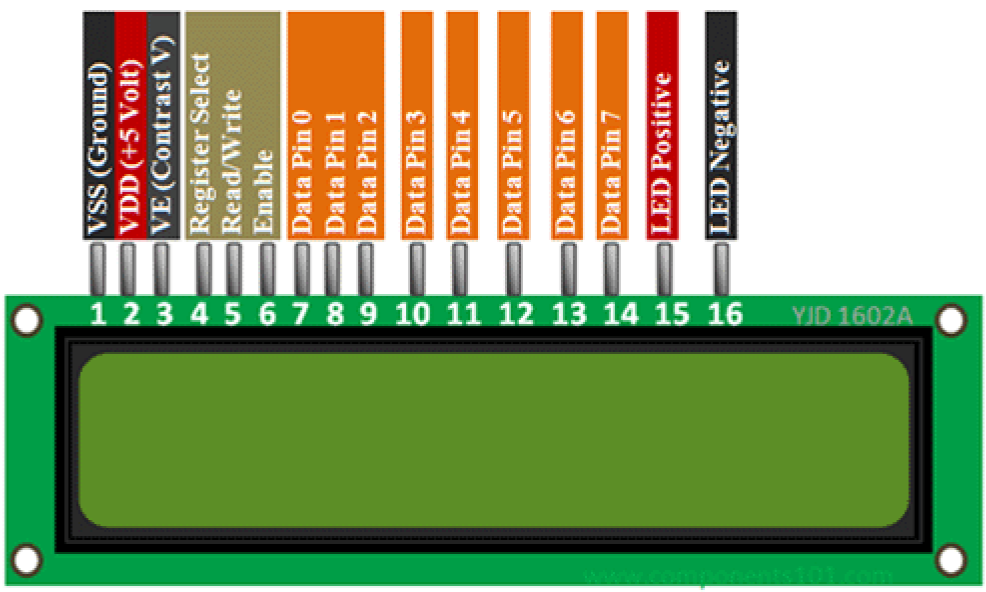


Figure 5.16 x 2 LCD display*[33]*

As explained above the display consists of 2 rows and each row can show up to 16 characters including letters and numbers. Each character shown in the display is built 5 by 8 pixel boxes. The display can work perfectly in both 4 and 8 bit mode. Also the display comes in 2 backlights green and blue one.

2.5. I^{2}C BUS

In the early 1980s, Philips developed the I^{2}C bus simplify the interaction between components along the same circuit on the board. Philips Semiconductors transferred to NXP in 2006.[32]

I^{2}C means "Inter IC." It is also known as the IIC or I^{2}C bus.

The initial communication speed was limited to 100 Kbit/s because many appliances do not need faster transmissions. Still exist a 400 Kbit fast mode. The high-speed 3.4 Mbit since 1998 become optional for applications that need it. It has been released a transmission rate between fast mode and this. There exists another mode: UFM mode also known as ultra fast mode; however it is not an I^{2}C bus.

I^{2}C function is to link components both through wire and on single boards. Because of its simplicity and adaptability, the bus is suitable for several of applications.[34]

The following are the most important features:

- Just two bus routes are needed.
- There are no specific baud rate constraints, as there are with RS232;a bus clock is produced by the master
- All components have simple master/slave relationships.Each device linked to the bus has a unique software address.

- I^2C is a genuine multi-master bus with collision detection and arbitration.

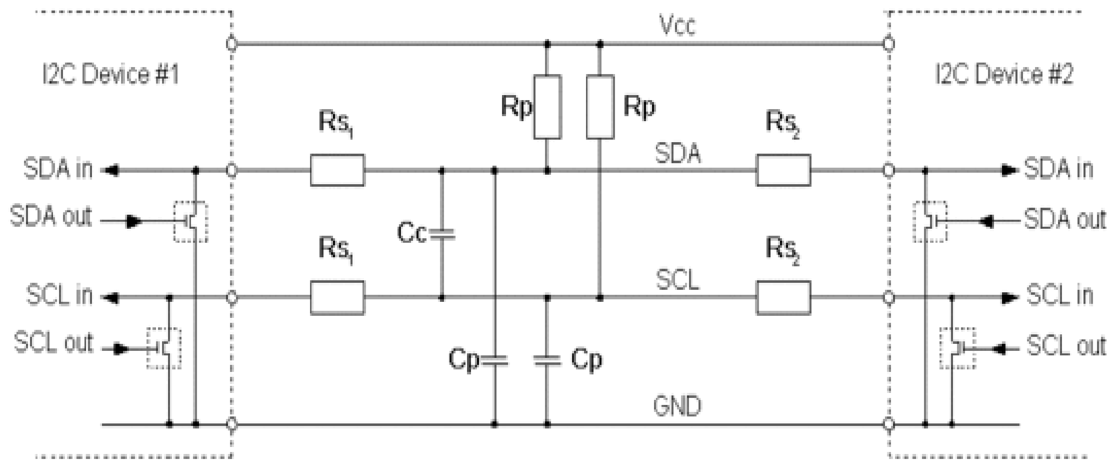


Figure 6. Circuit diagram for an I^2C connection between two devices *[35]*

VCC	Supply voltage 1.2 -5.5 V
GND	Ground
SDA	Serial data
SCL	Serial clock
Rp	Pull-up resistance known as I^2C termination
Rs	Serial resistance
Cp	Wire capacitance
Cc	Cross channel capacitance

The I^2C bus provides data and clock through SDA and SCL respectively. Before starting, keep in mind that SDA and SCL are open-collector (open-drain) lines, which means that the lines can only be drive or leave open by I^2C master and slave devices.

When there is no I^2C device present, the line is pulled up to Vcc by the termination resistor Rp[36]This offers features such as running several I^2C masters simultaneously period (if they are multi-master enabled), as well as tension(slaves can impede communication by restricting SCL).[37]

The temporal nature of the signals on SDA and SCL is influenced by the termination resistor Rp and the wire capacitance Cp. While I^2C devices use open drain drivers or FETs to pull the lines down to 10mA or more, the signal is returned to a high level by the help of Rp pull up resistance.[38]The pull-up resistance is typically between 1 and 10 k, leading in pull-up currents which are no more than 1 mA. That's why I^2C signals have a saw tooth-like look. In fact, the charge characteristic of the line is evident on the ascending end of each 'tooth,' and the opposite one is apparent just on descending end.

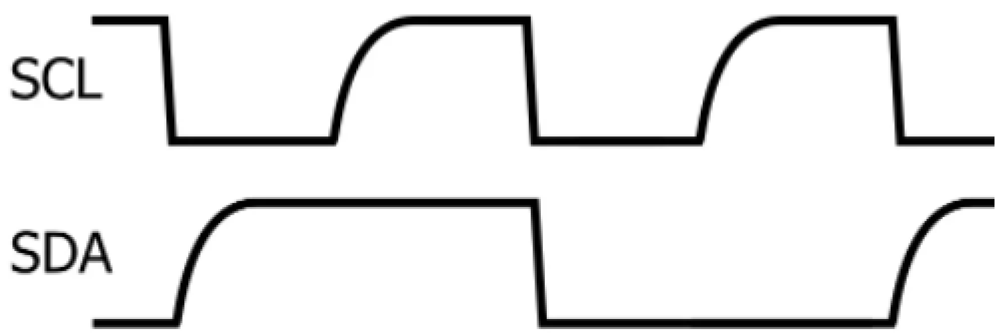


Figure 7.SDA and SCL graphic*[39]*

SDA below and SCL above with pull-up resistance = 10 kΩand wire capacitance= 300 pF. The SCL clock operates at 100 kHz.[40]

CHAPTER 3

METHODOLOGY

In the figure below is presented the diagram for the PLC.

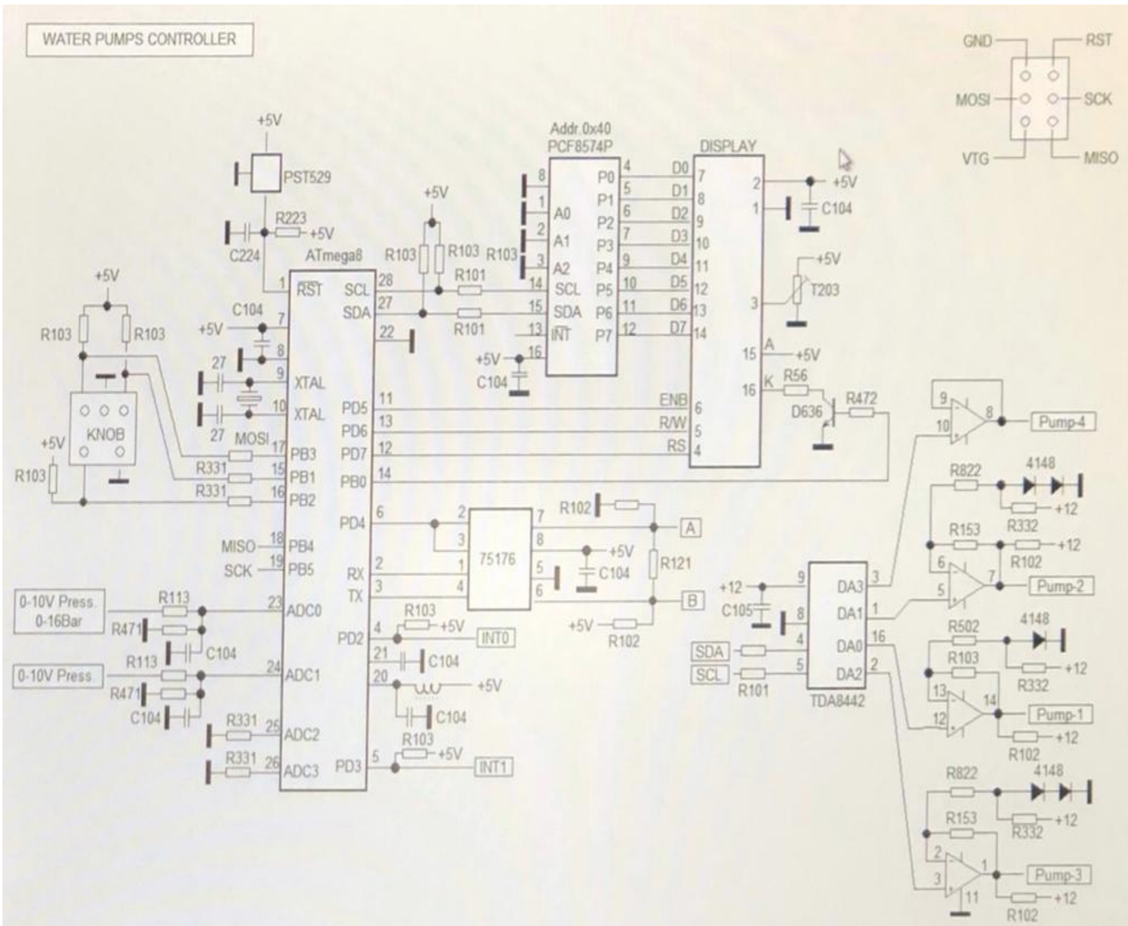


Figure 8.PLC (Programmable Logic Controller) Block diagram

The hardware model of the whole system, including the PLC circuit, phase converter circuit, and VFD coupled to the induction motor, has been implemented and is described in the diagram above.

When the frequency of the input source changes, the speed changes as well, this is the working principle of this thesis. The induced stator voltage is proportional to the flux/supply frequency product.

The faraday's law (induction) produced by a three-phase induction motor is identical to the transformer equation, assuming that

E or V =4.44 K.T.f.

When the voltage drop of the Stator is considered to be zero, E=V Vafϕ is obtained, where K represents the winding constant and T and f represent the number of turns per phase and frequency, respectively. The speed which is synchronous fluctuates when the frequency is changed, yet as the frequency falls, the flux rises. A change in flux value causes overload of the rotor and stator cores, resulting in an increase in the induction motor's zero load current. So, it is critical in this process to keep the flux constant as the voltage varies. When we reduce the frequency, the flux increases, but when we reduce the voltage, the flux reduces as well, therefore the flux remains constant. As a consequence, the V/f is kept same in this procedure, which is known as the V/f method.

When we supply varied voltage and frequency, the speed of the motor fluctuates; we will use the V/f ratio approach to regulate the speed of the induction motor.

With this equation

T α V/f,

a constant torque may be obtained for a constant V/f ratio.

Ns=120f/p

Because poles are integrated and cannot assist to speed control, the frequency of a three-phase induction motor can be changed.We may assert that the V/f ratio torque created is constant during the operation by specifying all parameters. In this thesis we are focused in V/f ratio.

By giving the input to the PLC via sensors and PLC read the input than show them on the display.Because the VFD cannot read digital signals, the PLC output is linked to the Analog Module, which converts digital signals into analog signals.The VFD, which receives power from three single phases connected at various locations, and the PLC output, which is received through the Analog Module. The V/f ratio will now be altered by using input signals from the PLC and a VFD. This entire process results in a change in the speed of the induction motor, which can be monitored in real time.

The most important hardware parts for the PLC are:

1. Power Supply – This part can be inside the PLC or can be external one. Common voltage levels needed to start up it are 12Vdc, 24Vdc, 120 Vac, 220 Vac. In this thesis we are using 12 Vdc.
2. CPU (Central Processing Unit) – This is a microcontroller where the program is implemented and processed. In this thesis we are using ATmega8.
3. I/O – The PLC can monitor the process and initiate actions, if a number of input/output terminals are be provided..
4. Indicator Lights – These might be tiny LEDs that show you the state of the PLC including power ON, RUN mode, and errors. Error LEDs are essential when diagnosing problems because each of shows a message that directs you to the problem.

PLC Board Construction

The board is built with a CNC machine by giving the coordinates for each line and holes on the board, which is much easier than building it in normal boards.

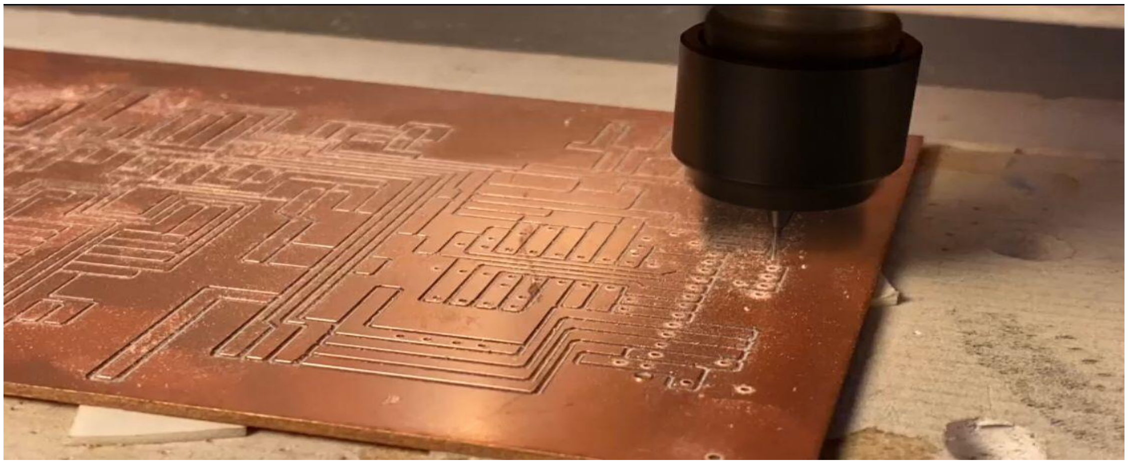


Figure 9.CNC machine

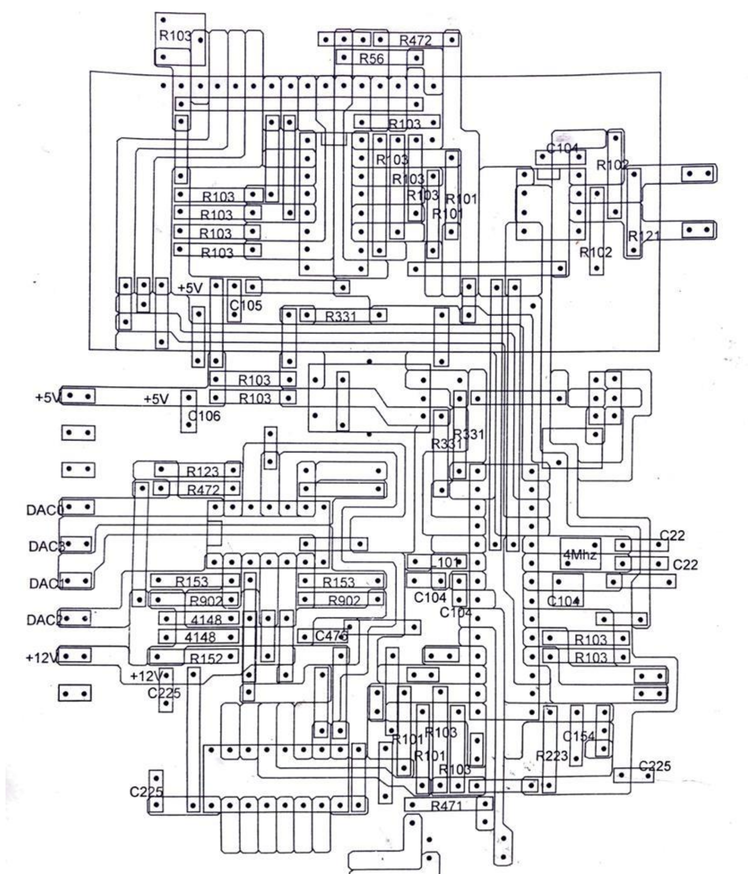


Figure 10.PLC scheme together with components

CPU ATmega8

The ATmega8 is a 8-bit CMOS microprocessor. By executing powerful instructions in a single clock cycle, the ATmega8 achieves bit-rate up to 1MIPS per MHz, letting the system developer to balance power consumption with processing performance.

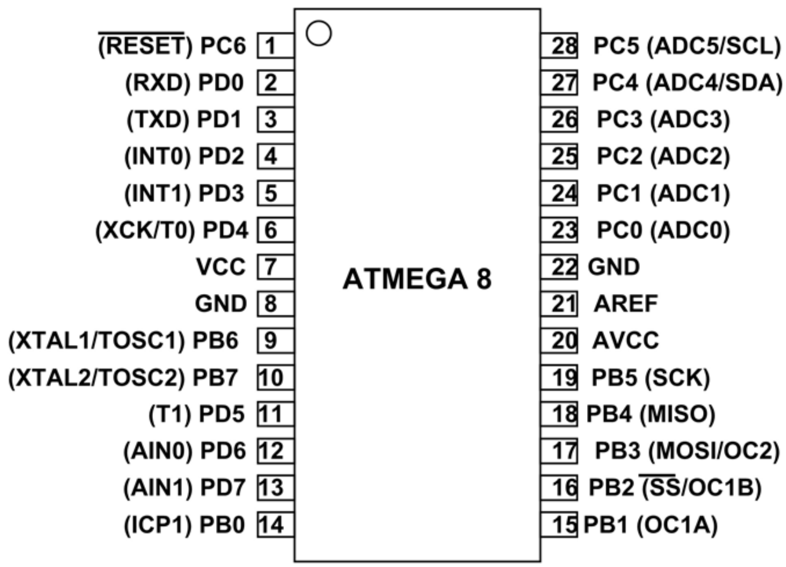


Figure 11. Microcontroller Diagram (ATmega8)

VCC	Digital supply voltage.
GND	Ground
PORT B	Port B is an 8-bit bi-directional I/O port with internal pull-up resistors
PORT C	Port C is an 7-bit bi-directional I/O port with internal pull-up resistors
PORT D	Port D is an 8-bit bi-directional I/O port with internal pull-up resistors
AREF	AREF is the analog reference pin for the A/D Converter.

AVCC	AVCC is the supply voltage pin for the A/D Converter
RESET	Reset input.

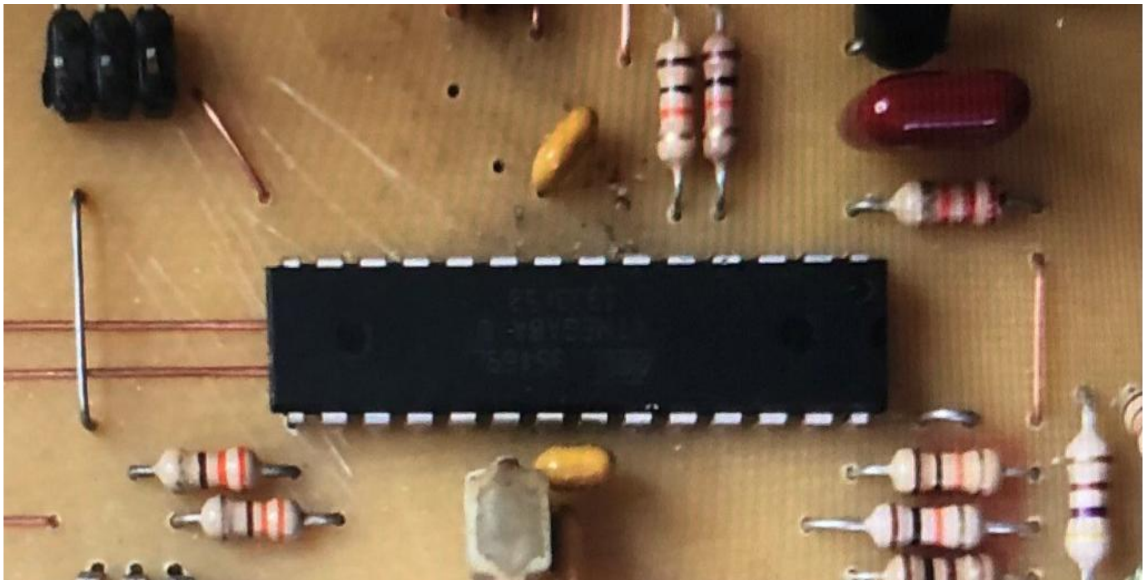


Figure 12. Microcontroller (ATmega8) on the board

The language used to program the ATmega8 is C++and the code is programmed to the processor by ATMEL programmer. The program is the control done by PLC and it can also be remotely controlled by its own software. The most crucial part of the program is shown in the figure below.

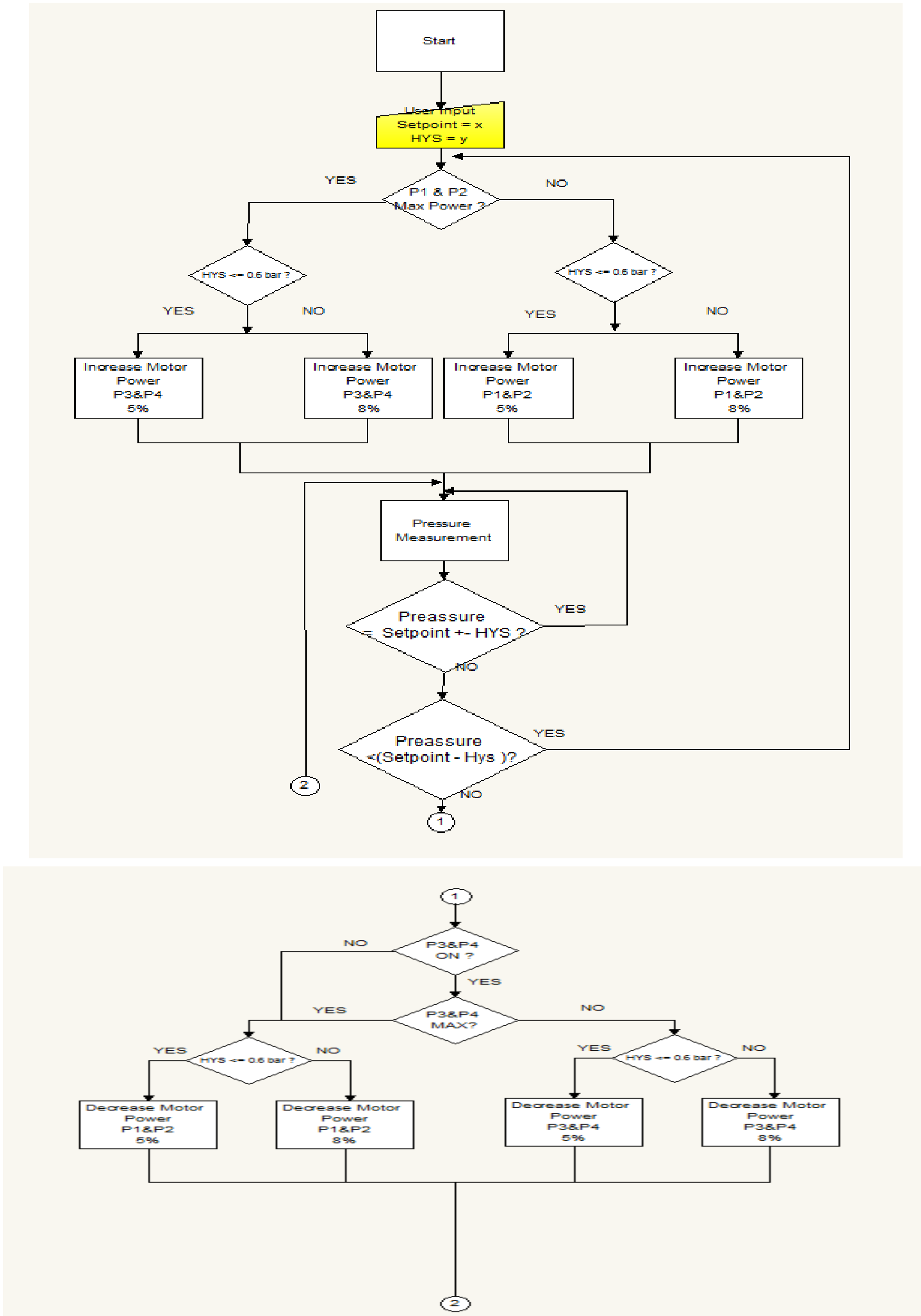
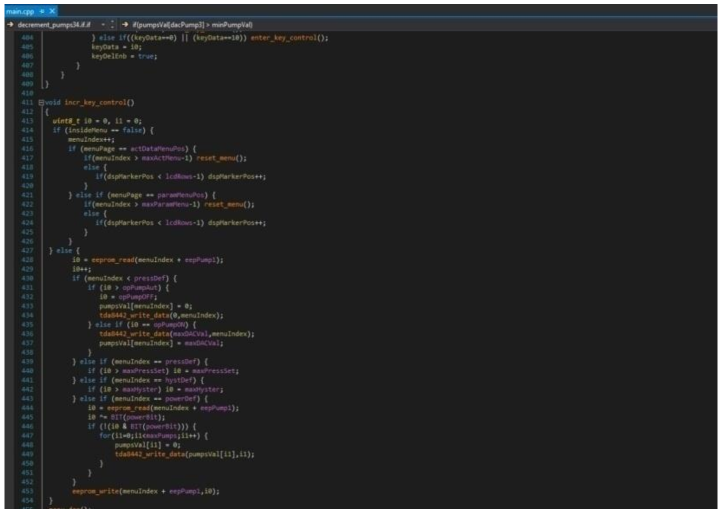


Figure 13. Flow Chart of the process



```
main.cpp
decrement_pumps34.if.if        if(pumpsVal[dacPump3] > minPumpVal)
            } else if((keyData==0) || (keyData==10)) enter_key_control();
            keyData = i0;
            keyDelEnb = true;
        }
    }
}

void incr_key_control()
{
  uint8_t i0 = 0, i1 = 0;
  if (insideMenu == false) {
      menuIndex++;
      if (menuPage == actDataMenuPos) {
          if(menuIndex > maxActMenu-1) reset_menu();
          else {
             if(dspMarkerPos < lcdRows-1) dspMarkerPos++;
          }
      } else if (menuPage == paramMenuPos) {
          if(menuIndex > maxParamMenu-1) reset_menu();
          else {
             if(dspMarkerPos < lcdRows-1) dspMarkerPos++;
          }
      }
  } else {
       i0 = eeprom_read(menuIndex + eepPump1);
       i0++;
       if (menuIndex < pressDef) {
           if (i0 > opPumpAut) {
              i0 = opPumpOFF;
              pumpsVal[menuIndex] = 0;
              tda8442_write_data(0,menuIndex);
           } else if (i0 == opPumpON) {
              tda8442_write_data(maxDACVal,menuIndex);
              pumpsVal[menuIndex] = maxDACVal;
           }
       } else if (menuIndex == pressDef) {
           if (i0 > maxPressSet) i0 = maxPressSet;
       } else if (menuIndex == hystDef) {
           if (i0 > maxHyster) i0 = maxHyster;
       } else if (menuIndex == powerDef) {
           i0 = eeprom_read(menuIndex + eepPump1);
           i0 ^= BIT(powerBit);
           if (!(i0 & BIT(powerBit))) {
              for(i1=0;i1<maxPumps;i1++) {
                  pumpsVal[i1] = 0;
                  tda8442_write_data(pumpsVal[i1],i1);
              }
           }
       }
       eeprom_write(menuIndex + eepPump1,i0);
}
```

Figure 14.C++ language of the microcontroller

In the board we have used anOCTUPLE6 bit DACs with I^2C bus called TDA 8444. In the figures below are shown the pin configuration and the place on the board of the bus TDA 8444.

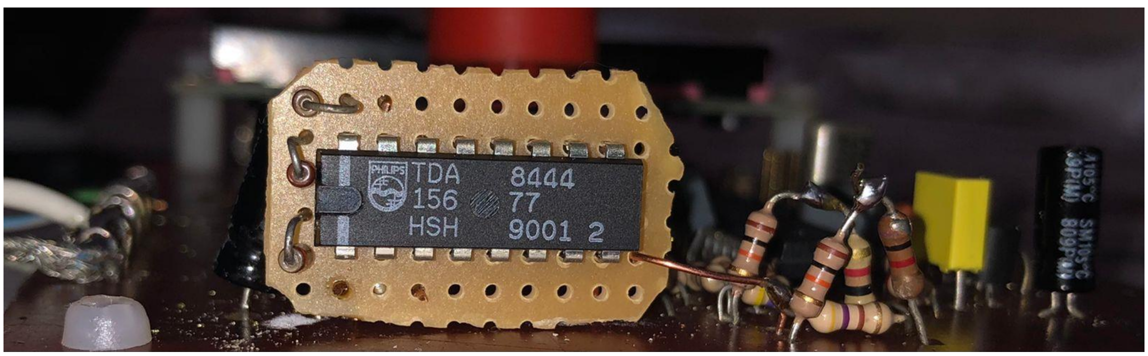


Figure 15. Bus TDA 8444

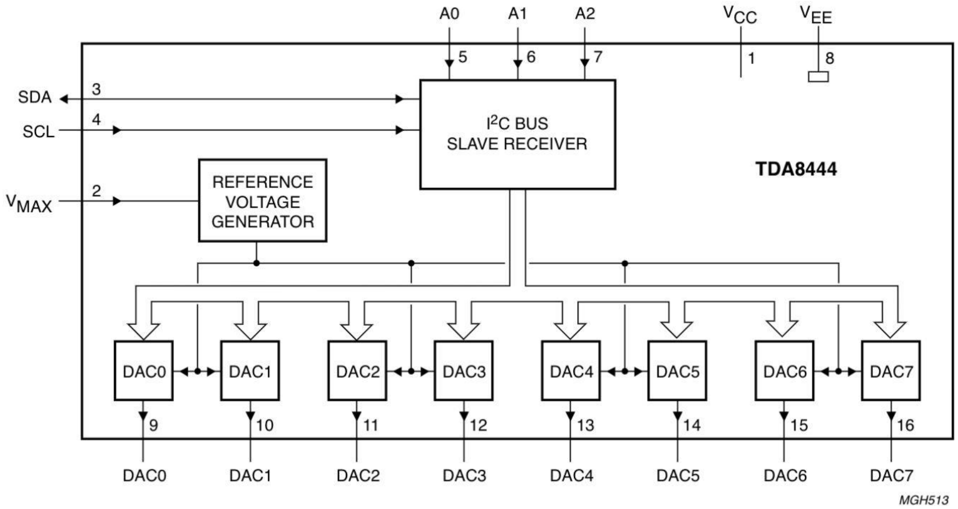


Figure 16.TDA 8444 Pin Configuration

In the figure below it is shown the interface of the software in order to remote control the entire system. You can check which pump is working the pressure and also the speed of the motor. Below the main part is the graph which shows the speed and the pressure in different time intervals.

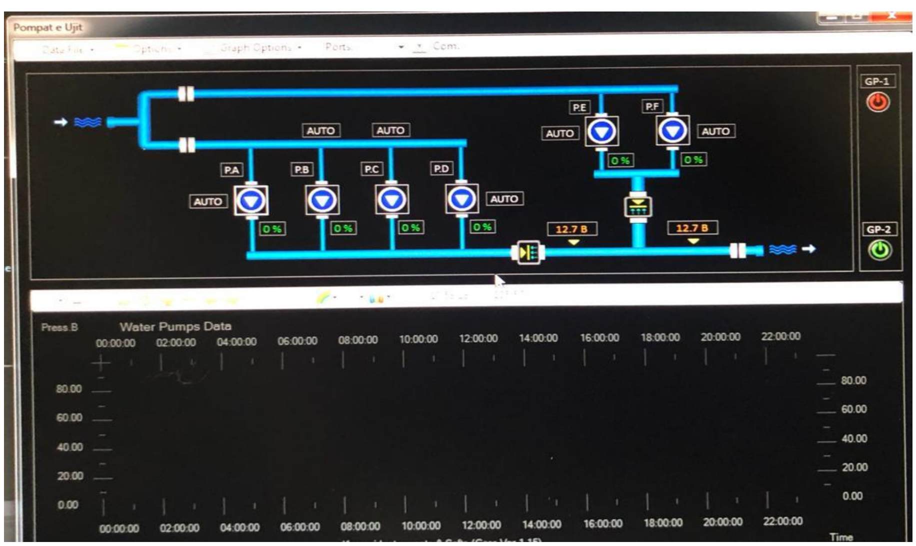


Figure 17. Software interface

CHAPTER 4

RESULT AND DISCUSSION

4.1. Result

The system has worked perfectly under different values gained from the sensors. In the menu shown in the LCD you can easily check how many "Bar" does the sensor show at the moment of working. Are three states of the motor ON, OFF and AUT. When the motor is at the ON position the information sent by the sensor to the processor doesn't do any effect on the motor because it will work with the speed given by the inverter but when the motor is at the AUT it will get information from the sensor and will work with the speed that is needed. At the OFF position the motor is not working. In the menu you can select how many motors you want to use and also the state of each motor. You can also put the SET POINT that you want to reach during the working state. Also you can put HYSTERESIS one of the most important values in the energy consumption and in the life time of the motor, because when you extend the value the motor will stop working until it reach the SET POINT value. This one will avoid frequent ignitions and shutdowns.

Figure 18.HOMEis the section which shows the pressure at the working state. It can easily be mount 2 or more sensors. In this case only one sensor is mounted

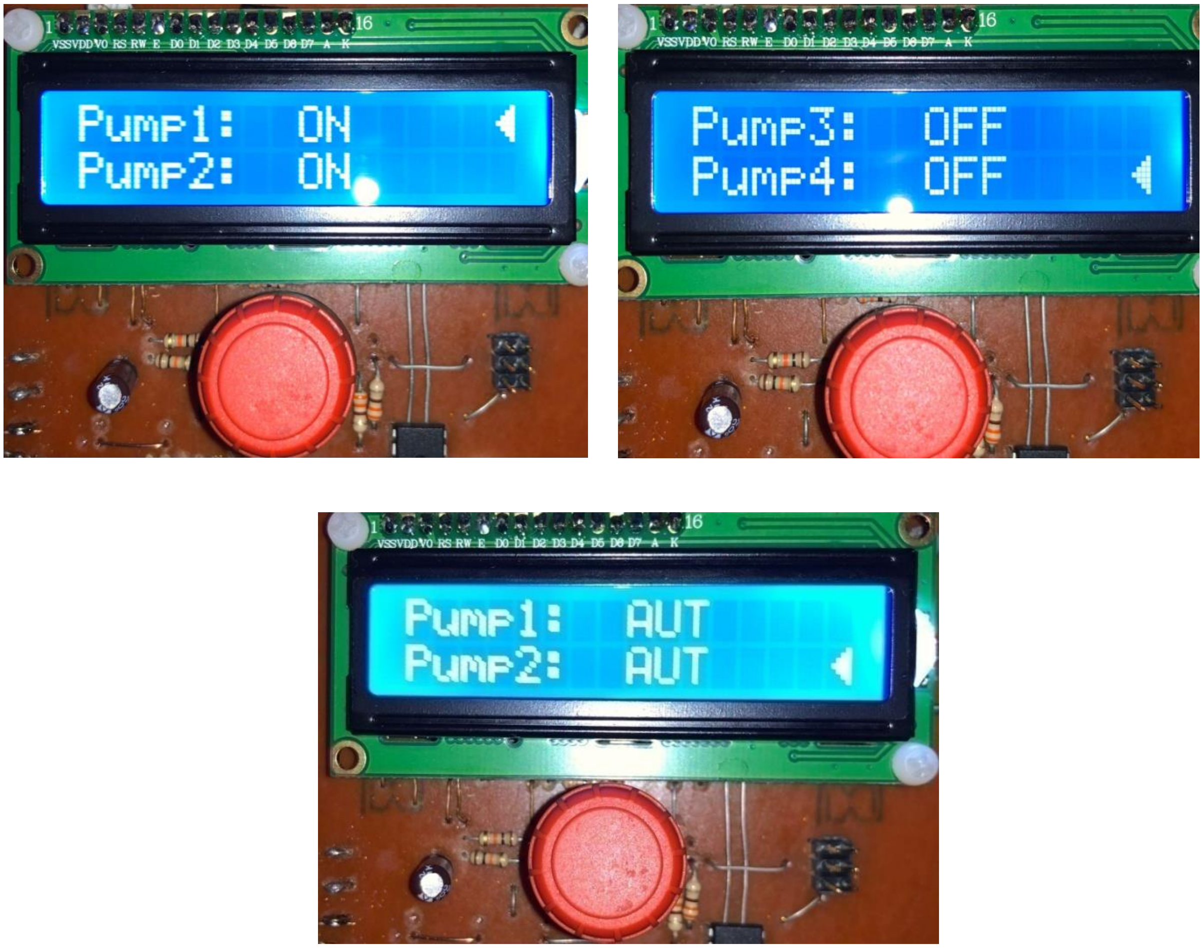


Figure 19. Three states of the motor ON, OFF and AUT

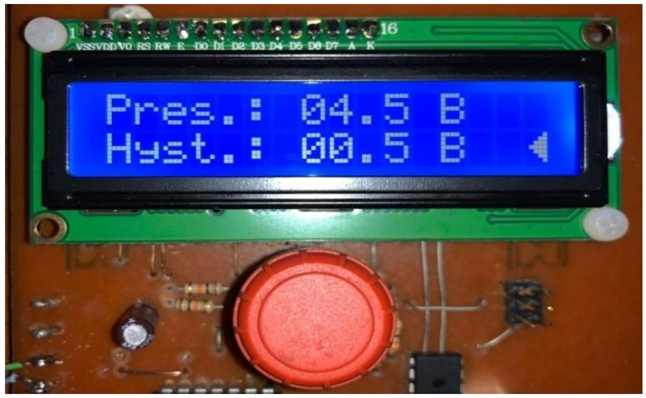


Figure 20.SET POINT and HYSTERESIS

Motor control will be fully automatic. It will work in a linear way and the motor will start one by one depending on the pressure. So if one motor cannot fulfill the needs the other motor will start working so it will continue even for the other motors. Even and vice versa if the pressure start to drop and the system is equilibrated the motors will stop working one by one.

	PREASSURE					
	0 B	**7 B**	**3 B**	**5.5B**	**9 B**	**7.5 B**
MOTOR 1 & 2	-	58 %	94 %	90 %	38 %	53 %
MOTOR 3 & 4	-	-	30 %	-	-	-

Figure 21. Measures are done during working with the SET POINT 7.5 Bar. As you can see the motors 3 & 4 start working when the motors 1 & 2 reaches the maximum power and they work all parallel and after the pressure is increased their power drop again to 0.

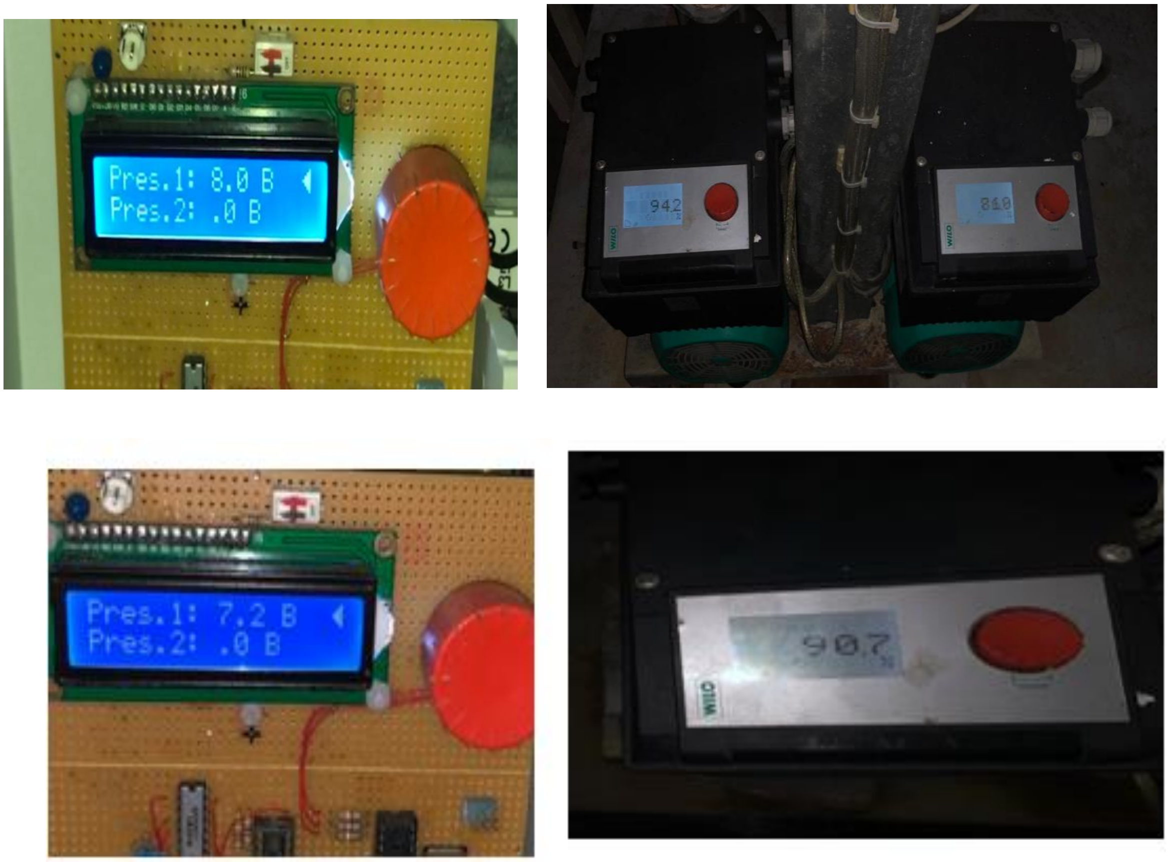


Figure 22.PLC mounted on the system. As you can see in 7.6 Bar with the SET POINT 7.5 only one motor is working with 90% of the power when the pressure drops to 5.0 the motor one reaches the maximum and the second motor starts working.

4.2. Discussion

In this thesis we have built a completely automated system. PLC is one of the most useful devices in today's industries. Together with PLC and VFD we have raised the efficiency of the three phase induced motor, the system works with full precision every motor starts when is needed and with the capacity that is needed. No more rough starts and frequently start and stops which means better motor performance, increased lifespan and also less energy consumption. In the literature review is explained above some of the researchers have managed to build an automated system with PLC and VFD, just a normal control of the motor speed. But in this thesis the real factor that controls the system is the press sensor that that goes 0-16 Bar (0-10 V). It is a numerical value that is converted from analog to digital in the processor, compared with the set values and then send a signal to BUS which convert it to analog again to give the in information to the motor to change the speed, stop or start. Even in this thesis we have done software in order to simplify the process and controlled it remotely without the need to be there.

CHAPTER 5

CONCLUSION

Many testes are done under different conditions to check functionality of both the hardware and the software and it is observed that they work in the perfect condition. In this thesis we are concluding that the speed, rotation and even the start-stop of the three phase induced motor can easily be controlled by Variable Frequency Diver and PLC and it is also a more efficient method because it is controlled remotely without the need to be there. So basically we have built an automated system. The PLC takes information from the sensor and then sends the proper frequency the VFD which it is translated to the RPM for the motor. The aim of this thesis is building a PLC in order to have an automated system in order to control the process remotely, reducing the cost of production, reducing the energy consumption and even increasing the life-time of the motor because it avoids those rough starts and it is working smooth during all the process.

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