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Bachelor's degree in Mechanical Engineering

TEST BENCH MONITORING

Memory

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Thanks

To my advisor Virginia who had lot of patient and guide me to the correct way. To the KIMUA GROUP company to offer me the opportunity to work with them giving me a real project to do.

ABSTRACT

The present project has been done in collaboration with Kimua Group. Consist on the monitoring of the test bench monitoring with the object to know in real time the behavior on the test bench meanwhile the load tests are being done. To this a series of phases has been followed which goes since the theoretical ones where multiple alternatives of electronic devices and sensors had been studied until the implementation one with the devices chosen for the bench test. With this project will encompass a future line work more complex to monitor Eolic tower lifting maneuvers in the North Sea.

RESUMEN

El presente proyecto se ha realizado en colaboración con la empresa Kimua Group. Consiste en la monitorización de una bancada de pruebas con el objetivo de poder saber en tiempo real el comportamiento de la misma mientras se efectúan pruebas de carga. Para ello se han seguido una serie de fases que van desde las teóricas, donde se ha estudiado las múltiples alternativas de equipos electrónicos y sensores, hasta la de implementación de los equipos elegidos para la bancada. Con este proyecto se abarcará una próxima línea de trabajo mucho más compleja para monitorizar maniobras de elevación de mástiles eólicos en el Mar del Norte.

RESUM

El present projecte s’ha realitzat en col·laboració amb la empresa Kimua Group. Consisteix en la monitorització d’una bancada de probes amb l’objectiu de poder saber en temps real el comportament de la mateixa mentre s’efectuen probes de carga. Per això s’han seguit una sèrie de fases que van des-de les teòriques, on s’ha estudiat les múltiples alternatives d’equips electrònics i sensors, fins la de implementació dels equips escollits per la bancada. Amb aquet projecte s’abastarà una pròxima línia de treball molt més complexa per monitoritzar maniobres d’elevació de màstils eòlics en el Mar del Nord.

Summary.

List of figures.

List of tables.

Acronyms.

ADC	Analog to Digital converter
AI	Analog input
DAQ	Data acquisition system
I/O	Inputs/Outputs
MVP	Minimum value product
PLC	Programable logic controller
PSU	Power supply unit
VDC	Volts direct current

Terms

DIN43650 C	Kind of connector which is cube form with 4 wires
G 1/2''	Type of thread
G 1/4''	Type of thread
M12 4 pin	Kind of connector which is metrical 12 with 4 wires

1. Project's goal.

1.1. Purpose.

The project's purpose is the design and implementation of a control device in the test bench of Kimua Group while a load test is being done to obtain data. Recompile data of the design to allow in future lines to monitor Eolic tower lifting maneuvers.

1.2. Finality.

The end of the project is to monitor the test bench to see in real time what is happening. Obtain data with a computer and see it with a screen, which is useful to know the behavior of the test bench and the tools tested.

1.3. Object.

The project's object is the design and installation of the chosen devices on the test bench to monitor it and obtain data in real time with a displacement-constraint graphics. This will give us crucial information and see what is happening, saying where are the most deformation and strength.

1.4. Project's scope.

Find the appropriate sensors, which are distance and pressure ones, choose the device which is better to do the acquisition of the data obtained with the sensors and do all the devices work together and mount all the sensors in the test bench. With this will achieve the information we need.

2. Introduction.

To achieve this project different phases had to been followed due the complexity of itself. As the project was being studied, different ways appeared and the line of the project change couple times. These phases become more complex and more focused on the problem to solve as they increase, starting with the phase 1, which is the theoretical one to the phase IV which is the final one and with this we will be able to monitor the test bench.

The future line of the project is focused on the monitoring maneuvers with heavy components, especially with the transport and installation of the wind towers offshore. This will not be done, as we said is a future line but with this project we will obtain useful data and will learn how to receive this data with sensors. With this knowledge, the company of Kimua group [1] will be able to do the next step of the project.

The company offer us the different scenarios they work with and those are lifting maneuvers, load test and transport as we can see on the table below. Also, there we can see the devices needed in each scenario and will help us choose the easiest one with a simple diagram.

		LIFTING MANEUVRES		LOAD	TRANSPORT
		ONSHORE	OFFSHORE	TEST	SEA AND ROAD
CONNECTIONS	CABLE			X	
	WIRELESS	X	X		
WIND (m/s)		X	X		
TEMPERATURE (C°)		X	X		
MOVEMENT (GPS)					X
ACCELEROMETER (m/s^2)		X	X		X
DISTANCE (mm)		X	X	X	
PRESSURE (Bar)				X	
VIDEO (camera)		X	X		
BATTERY					X

Table 2.1 Minimum value product for scenarios

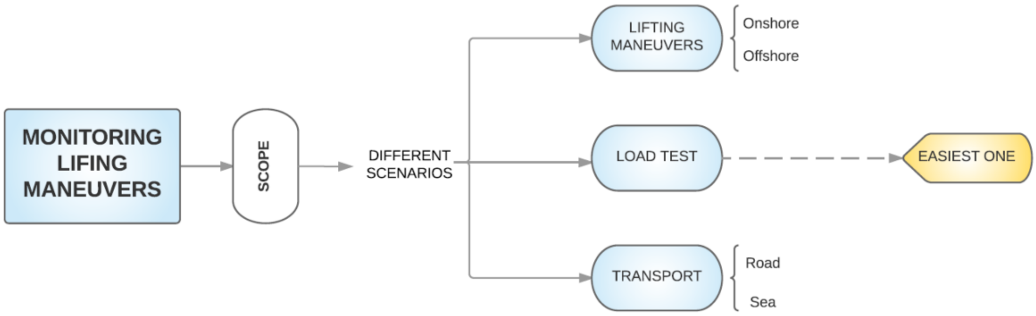

Figure 2.1 Diagram different scenarios

As we can see the easiest one is the Load test because is the one who has less sensors or devices to achieve the monitoring of the test bench. This scenario appears when on the company they have to design and build a tool to do liftings. Then they have to test it in their test bench before selling it.

Then this project is based on the design and implementation of one prototype to do the monitoring of the test bench of Kimua group situated on the Vasc County in real time and allow them to see a displacement-constraint graphics. Moreover, is a good place to start with because is a controlled scenario where are no risks and you can do as many tests as the situation requires. The design is focused to do it in a portable module form ‘a box’, which must be resistant to the harsh conditions, water proof and perfectly withstand the high work conditions, also all removable to be able to transport the equipment in case of the need. This prototype will consist in different kind of sensors as distance and pressure, a computer and a device to receive data.

The finality is to monitor their test bench to receive all the data in real time with a DAQ and one computer, with these devices will be able to obtain a graphic of displacement-constraint directly while they are doing the test.

To delimit the extent of the load test project, the specifications are:

- Find the distance measurement and pressure sensors for the test bench
- Find how to connect all the sensors
- Find cover case to do a portable box
- Build a functional prototype

- Do the program with the software LabView
- Find which device of acquisition data is needed for the project
- Do a planning of the project
- Determine where the pressure and distance measurement sensors goes on the test bench
- Do mechanical and electrical plans
- Do economical study
- Do the planes of the designed pieces

This project will not include:

- Programming complex software
- Other applications of the prototype
- The next step prototype for the lifting maneuvers, it is a future line

3. State of art and information requirements.

In this point will see the state of art of the project, analyzing how this technology is developing nowadays, the information required to achieve this project.

3.1. State of art

The hydraulic systems exist from many years ago, the devices had changed with the time but the main functionality is the same, hydraulic oil with pressure [2] which receive pressure from a pump which allow us to lift weights or move structures with the help of a cylinder. Nowadays the hydraulic monitoring systems are being used in almost all areas such as automotive industry, industrial machines and aircraft industry among others. This is due to all the benefits that provide, like it is easy to regulate the pressure and it is able of support overloads without warming out.

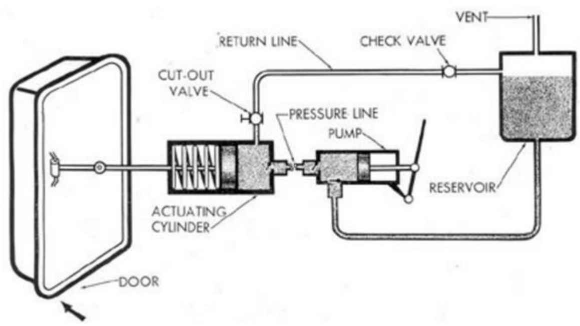

Figure 3.1 Scheme basic hydraulic System [source: maritime.org/]

As the hydraulic systems are being used more and more, there is a necessity of improve and do the equipment better and safer. A new way which appears on this years ago is to monitor the equipment, to know the pressure and the distance done by the cylinders and pump, first were monitored by analog systems but now those are being substitute by digital sensors [3] Digital sensors are cheaper than analog and the signal is not affected by the electrical noise.

Nowadays, there are different companies offering hydraulic monitoring solutions like Lekang group, EATON, Fozmula, Kittiwake, among others. The mentioned companies are not focused only on offering hydraulic solutions, instead are companies based on offering engineering solutions for other companies. Those companies are able to offer a personalized hydraulic monitoring solution for every customer. It has not been found any company which offers a standard industrial solution, such as a kit or all in one product for monitoring industrial hydraulic systems.

A study has been carried out in order to obtain value information about patents that might interfere with the development of the project. It has been found one patent [4] that offers a similar solution to the one explained in this project and is shown below.

Patent title: control method and controller for mechanohydraulic system

Patent code: US8099196B2

Publication date: 2012-01-17

Inventor: Georg Keintzel, Gernot Grabmair and Kurt Schlacher

Patent description:

The invention relates to a control method for a mechanical-hydraulic system having a degree of freedom per hydraulic actuator which is embodied as a control path, and a measuring sensor which is used to measure the pressure p_h of a hydraulic cylinder and a measuring sensor which is used to measure the position x_h of the piston of the hydraulic cylinder. A control unit which can receive input variables of hydraulic pressure p_h, and hydraulic actuator position x_h, is provided. An observer, which determines the desired pressure of the hydraulic system and the speed v_h of the hydraulic actuator, is implemented in the system. The desired pressure in the control element is taken into account in the set of rules of the control element and the speed v_h of the hydraulic actuator can be over-ridden for attenuating the control element.

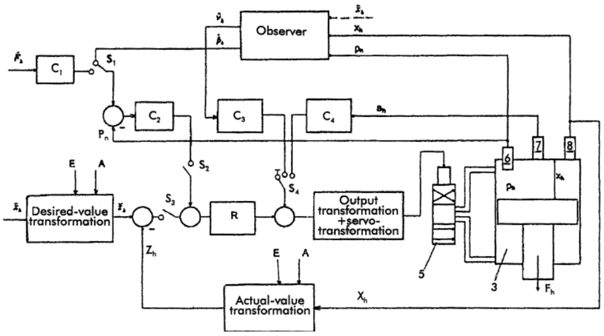

Figure 3.2 Patent ilustration

As we can see a device like we want to design in this project does exist yet, but how it does affect to us? We want to improve an existing test bench of the company Kimua and with this project they will be able to obtain data in real time with graphics where they will see the pressure and the distance done by the cylinders hydraulics, moreover, will obtain accurate information while they are doing load tests about the frame of the test bench. The intention is to have it internal, only to do the tests safer and this device will not be for sale. Then we can conclude this patent does not effect on our project.

Once the project will be finished, we mentioned a future line to continue and will aboard the monitoring of the Eolic tower lifts. For this we can say there is no lot of companies who do this kind of lifts due the complexity of it. There is not a project or something similar on the market, there are companies who offer the monitor of some parts in their lifts and are some who offer systems of hydraulic cylinders who are controlled electronically, but there is not a company known which does the monitoring of Eolic tower lifts.

There are some different systems on the lifts which give us valuable information and could help us to know the wind, temperature and the position of the object you are lifting. Moreover, the help of the people outside the lift who are constantly communicating with the lifter, but there is nothing in the market which give us the position and the velocity of the object while the lifting is being done in real time. So, there is not a device or machine which does the interaction between all the sensors and cameras.

There is a company named FAGIOLI [5] who does something similar. This company does enormous lifts, up to 25.500 tones offshore and transportation of huge pieces. Moreover, they monitor the lifts but in other way, they do an Automatic synchronization of lifting speeds irrespective of loads, Pre-set overload protection, automatic lifting and lowering without any personnel in attendance at the jacks…while they are doing the lifting to make them safe.

FAGIOLI’s device is like the one what Kimua is willing to achieve, however it is not as complete as theirs.

A possible future lines too is to offer this device to the companies who does the lifts, is not necessary the lifting of the towers, could be anyone just changing some sensors or doing a reprograming of the software, to have a real-time monitoring and know exactly what is happening. With this the liftings will be safer and more accurate.

The objective of the project is this, but as we said before to achieve that first will do a device to monitor the test bench to gain experience on the field of the acquisition data, to achieve this will need to have specific equipment or devices, which ones have specific characteristics who can do the optimal operation of the monitoring. With this the tests done will offer more information such as the position and pressure of each cylinder, moreover will tell if the bench itself is suffering some kind of deformation.

3.2. Information requirements

To achieve the project is required to search information in some fields as are shown below:

- **Information about sensors.**

  There are many sensors to monitor the test bench, first we have to focus in which ones we need to monitor the test bench. We want to receive data about the distance done by the cylinders and the pressure inside each them, moreover, we need the ones which will give us all the data to know what is happening at real time, it means those sensors have to have an electronic part who gives us the information, so the analog ones are not useful for this project doing the search of the sensors bit smaller. For this project then only two types of sensors are required:

  - Pressure sensors. This kind of sensors allows us to know the pressure in hydraulic systems. Can be mounted on distributors, hoses, outlets of pressure bombs or inlets of hydraulic cylinders. As we want to measure the exact pressure in real time on the four hydraulic cylinders, four pressure sensors are required to monitor the pressure and obtain the data.
  - Distance sensors. In this case we have to separate it in two groups, due that Kimua wants to know the distance done by the cylinders and the possible deformation due the load test on the test bench. The first group then is four sensors who will measure the distance done by each cylinder and the other group is four sensors as well, but those will measure different parts of the test bench giving us information about the frame. With those sensors will see if is suffering deformations while the tests are being done.

- **How receive the data.**

  If we want to monitor the test bench means we need a device which allow us to receive, interpret and give us the data received in real time. As is mentioned before, the sensors will be analog and will have a total amount of twelve sensors. With this previous information we can search for a device which accomplish these specifications and there are some devices on the market which allow us to do this such as DAQ’s (data acquisition system), PLC’s (programable logic controller) or specific computers. Those devices have a common denominator and it is they need specific software to run. Some of them have common software as CC or Java among others but there are some kind of devices that has their own software which is unique for them. With a further study about the devices, will choose the required one for the project.

- **Type of connections.**

  The sensors are analog, that means they must have a connector to allow us to plug it to the pertinent devices. This project will not do wireless transmissions, means we need wires and connectors to connect all the necessary devices for the project. There are many forms to connect wires to sensors or devices but some of the sensors have a common connector as it could be the M12 4 pin or DIN43650 C. The idea is to find sensors with the same type of connectors to do easier at the time of mounting or dismounting of the devices.

- **Computer and software.**

  This could be the most important part of the project. The computer with the respective software is crucial to receive the data, interpret and use the data acquired, also should do the interaction between all the sensors and the user. Moreover, the software must give us the possibility to program to our liking to adapt it to our project. The computer has also to be powerful enough to have the capacity to support all the programs used on the project. With this will have the displacement-constraint graphic that they are looking for.

- **Find a portable box**

  To monitor the test bench we need sensors, wires, computer among others, the idea is to have an equipment for the test bench which will be on the same while the load tests are being done, but once these tests are finished all the sensors will be storage on a box to avoid possible damages on the equipment. Moreover, this box must be on a portable form to allow us to move the equipment in case there is the necessity of move all the equipment, doing the portable box resistant to protect the equipment.

4. Project objectives and technical specifications.

Before an exhaust study about the information obtained, the study of the state of art and according to the object of the project which is the monitoring of the test bench, have been determined the objectives with their associate technical specifications.

Objectives:

- Measurement of the hydraulic cylinders.
- Measurement of the test bench frame.
- Pressure hydraulic cylinders control
- Do the data acquisition
- See everything on a computer
- Find a storage place for all the devices
- Power supply of the sensors
- Connections between the wires

Technical specifications:

- Distance measurements:
    - The total displacement of the cylinder is 300 mm, so the sensors will have this range of measurement.
    - Power supply of 24 VDC.
    - 0-10VDC analog signal output.
    - Error of ±1%
    - To measure the possible deformation of the frame, will use the same sensor of the cylinder measurement but with a range of 100 mm.
    - Connector DIN43650 C

- Pressure measurement:
    - Range of measurement from 0 to 1000 Bar
    - Power supply of 24 VDC.
    - 0-10VDC analog signal output.
    - Error of ±1%

  - Connector DIN43650 C
  - Sensor to screw
- Acquisition data
  - Minimum 12 analog inputs
  - 0-10 VDC inputs
  - Power supply by USB
  - Analog input 16 Bit

- Computer
  - Minimum processor i3
  - Minimum 4 GB memory RAM
  - Minimum 250 GB hard disk
  - USB port
  - Portable laptop

- Power supply
  - Inlet power supply of 220V
  - Outlet power supply of 24 VDC
  - Minimum 2 A

- Connections
  - Between sensors and wires DIN43650 C
  - To connect the wire to the DAQ the M12 4 pin

5. Technical solution.

Due the complexity of the project we divided it in different phases where we can see explained below.

5.1. Phase I

This phase was the first one and everything was theoretical. Here was more about the study of the devices on the market and see if something similar exist nowadays.

A study of the different sensors was done to see which ones were the most appropriate for this project. At the beginning, we found many different kind of sensors, as we had to do the cylinder measurement either the distance and pressure we stared to search for these sensors. After an exhaust study, the linear potentiometer sensors for distance were chose, not one model in concrete but the type of the sensor. The same about the pressure sensor, after seeing the different types of it the pressure transmitter piezo-resistive was the chose one.

Soon as we know the type of sensors we want to the project, a device to receive and process the data was required. At the project's beginning the MVP (minimum value product) was the model followed, which is a way to do a task or work using the less things you need to achieve it. Following this method, a cheap and theoretically easy device to program was chose to do the recompilation data.

When all the search and information was studied and the type of sensors and recompilation device was chosen, we started to work with the second phase.

5.2. Phase II

In this phase, we did the tests with the recompilation device chosen. To begin with the acquisition data, we started with a small computer with digital I/O, the Raspberry Pi 3 [6]. This device fit in with the MVP plan and theoretically with it the programming was supposed to be easy. Moreover, on the field of the acquisition data, thanks his open software and multiple number of I/O that in this case the Raspberry has 40, the device offered all we need. Also, was a cheap device with a wide range of alternatives like open programable software which was very striking compared with other devices which you had to pay for the software.

The project started with the Raspberry, doing small problems and programs to learn about this small computer. Once we knew how it worked we realized all the sensors required to this project were offering us analog outputs, of 0-10 VDC or 4/20mA. As the Raspberry does not have analog inputs, only digital, an ADC converter was necessary to receive the data of the sensors. A small program had to be done to do the interaction between the ADC and the Raspberry then, with the help of a PSU (power supply unit) changing the voltages we started to receive data.

The data acquisition was done through the ADC, plus the low power of the device did that the acquisition data started to be complicated, and was not exact with some fails.

Soon we saw this device was small and not the best one for the project we wanted to do. The power of his CPU was not enough too, was a slow device and with the ADC the interaction sometimes fail. Quickly we realized was not a good idea to continue with it.

Due this the utilization of the Raspberry was canceled because we saw was not enough for the specifications needed for the project, then we proceed to do a new phase.

5.3. Phase III

A new research of acquisition data systems was done due the failure of the Raspberry. Many devices of acquisition data were found but, mostly of them were without software or a specific one which requires a wide extend of knowledge about programming, in this part, these devices were more difficult compared with the Raspberry. After a study of all the devices found, an USB DAQ of National Instruments [7] device was found and seems to be perfect for our project.

National instruments is the biggest and the best company in the field of acquisition data, also they have a really good customer service with lot of exercises and tests to do in their web page so, we decided to this project with one of their devices. This device work with specific software, the LabVIEW. This was a big point to decide about this device because this software was a graphical one, it means you don’t have to have specific knowledge about programming. Thank to this, the programming work is less complicated and does this device perfect to the project.

The project scope was to monitor the test bench which has four hydraulic cylinders, for this four distance sensors and four pressure sensors were needed for the measurement of the cylinders. Moreover, Kimua wanted four distance sensors more to measure also the frame of the test bench but by the end that was not difficult because the distance sensors could be the same as the cylinder ones but shorter.

Once we had all the equipment chosen we proceed to contact with the providers to achieve the better price. At least 5 providers were contacted and we had one personal interview with the representative of National Instruments who help us on the DAQ selecting. The reason why we arrange the met was due the software of the DAQ. This cost around 1300€, plus the DAQ that it was around 700€ more. This made the acquisition of the DAQ bit difficult due the price but discussing with him he offered us a student license without cost, thanks that we decided to buy this device.

5.4. Phase IV

At the end, when all the information required was enough and concise the material was bought, can ask for the invoices on ANNEX I All of it has between two to four weeks delivery time so, to take advantage of shipping time we started to do the program with the software LabVIEW. by the end we decided buy all the devices. As the delivery time was about three or four weeks we decided to start doing the program. To achieve this, before we had to put in contact with the dealers of the National Instruments was done to do the sensors work at the same time before going to the Kimua group basement and all was tested to see their correct functioning.

5.5. Methodology phase IV

Next is the explanation of the phase IV, which devices and why were chosen, how the design about the implantation of the sensors was done and the electrical and electronical blueprints.

5.5.1. Chosen devices.

There is a common denominator on the selection of the devices to this project such as the facility of the connections to do the implantation easier or the output signals when we are talking about the sensors. Those ones should be analog as is commented before with a output signal of 0-10VDC and with a power supply of 24VDC. For the computer, we need a small and powerful laptop who will allow us to do the programming and see the graphics we are looking for. To finish a portable and resistant box to fill everything inside is needed to fill all the equipment inside while is not used.

The most important one could be the price of those devices and the further things you can do with them. The maximum budget for the project is between 3000€ and 4000€, that means the price is so important too at the time of the choice.

With those characteristics, the chosen devices are:

Cylinder measurement: To do the measurement of the hydraulic cylinders will choose a linear position transducer model ELPM-300. A linear position sensor measures the linear position of a device. The sensor reads the measurement in order to convert the encoded position into an analog signal. This position can then be decoded into position by a digital readout or a motion controller. Motion can be determined by change in position over time. with all the specifications shown below. For more information consult ANNEX II.

- Power supply of 24 VDC
- 0-10 VDC analog signal output
- 303 mm measurement range
- Linearity ± %0.05
- Minimum body length between pivot heads 472 mm
- Plug DIN43650 C

Frame measurement: To do the measurement of the frame of the test bench will choose a linear position transducer as well but in this case, will be the model ELPM-100 with the same specifications of the ELPM-300.

- Power supply of 24 VDC
- 0-10 VDC analog signal output
- 103 mm measurement range
- Linearity ± %0.05
- Minimum body length between pivot heads 272 mm
- Plug DIN43650 C

Pressure measurement: For the measurement of the pressure of the hydraulic pistons will choose a piezo-resistive transmitter which is PAA-21Y. A Piezo-resistive pressure is a sensor which contains several thin wafers of silicon embedded between protective surfaces. The surface is usually connected to a wheatstone bridge, a device for detecting small differences in resistance. The wheatstone bridge runs a small amount of current through the sensor. When the resistance changes, less current passes through the pressure sensor. The wheatstone bridge detects this change and reports a change in pressure. which give the specifications shown below. For more information consult ANNEX III.

- Power supply of 24 VDC
- 0-10 VDC analog signal output
- 2 to 1000 Bar pressure range
- Linearity ± %0.25
- Plug DIN43650 C

Computer: The computer is an electronic device which receive information and doing sequence of operations through programs produce one result. For this project, the computer must be a small laptop, who has to be strong and be able to resist harsh conditions. With this the selected computer is the Lenovo ThinkPad Yoga 12.5", which is waterproof as well and offer us his specs. For more info consult ANNEX IV.

- Processor i7 2.4 GHz
- 256 GB memory SSD
- USB 3.0
- 8 GB

- Touch screen

Data acquisition system: This device is the most important part on the project, so for that is explained in detail below.

The DAQ hardware interact between the computer and the signals of the exterior. It works mainly as a device which digitalize input analog signals to do the computer can interpret them. The three key components of the DAQ used to measure a signal are the signals conditioning circuit, ADC converter (analog to digital) and a computer Bus.

Next is the explanation of these three parts on the DAQ:

- Signal conditioning circuit:
  The signals of the sensors could be noisy or dangerously to be measures directly. The signal conditioning circuit manipulates the signal doing this appropriate to be measured and plug it in an inlet ADC. This circuit can have amplification, filtering, attenuation and isolation of a signal.
- ADC
  The analog signals of the sensors should be converted into a digital before to be manipulated though a computer. The ADC is a chip which proportionate a digital representation of an analog signal in an instant of time. In the reality, the analog signals are variating continuously on the time, and the ADC does periodic samples which are transferred into a computer through a Bus, where the original signal is rebuild from the software samples.
- Computer Bus
  The DAQ systems are connected into a computer trough a port, the Bus is the communication interface between the DAQ and the computer to pass the obtained data. The DAQ systems offers the normal Bus connections, such as USB, PCI, PCI express and Ethernet, the new ones offers Wi-Fi.

As we want to do the programming on the easiest way, the chosen DAQ system is from National instruments who offers a graphical software which is easy to program. The USB 6210 is the best solution because offer this specs. For more information consult ANNEX V

- 16 analog 0-10VDC inputs
- USB powered

- Easy programming
- 16 bits

Storage box: This should be strong to resist the harsh conditions of the work and in portable modus in case there is a necessity of transport. Also, is wanted to have a kind of table to put all the measurement stuff, for this the chosen box is the Thon DJ-Live Rack 16U with this general specs. For more information consult ANNEX VI.

- 41.3 kg weigh
- Dimensions 558 x 568 x 1198 mm
- 7mm birch plywood
- Service down door 350 x 450 mm
- 4 wheels to transport

Figure 5.1 Portable box [Source: www.thomann.de]

Wires: To connect the DAQ with the connectors we need wires. Those should have four cables, with different color each to cover the four pins that the connector has. The distribution of the pins with the colors is the next:

- PIN 1. Negative -24 Vdc. Brown wire.
- PIN 2. Output analog positive signal 0-10V. Green/yellow wire.
- PIN 3. Positive +24 Vdc. Blue wire.
- PIN 4. Ground analog signal. Grey wire.

As we have three groups of sensors and all have the same connectors and wires, a code of colors for each was chose to separate it quickly. The groups are:

- Yellow: pressure sensors
- Red: distance sensor 300mm
- Blue: distance sensor 100mm

Power supply: This is in charge of the power supply of all the sensors. As the sensors cannot be powered directly to the 220V we need a transformer to low the current into 24 V and transform it from direct current to continue current. The chosen one has the specifications shown below. For more info consult ANNEX VII:

- Input 220V
- Output 24VDC
- 10A of current

5.5.2. Cylinder measurement.

To measure the operation range of the cylinders we need to install them on the same body of the cylinder or on the frame of the test bench which we know will do the same distance of the cylinder. On the figure below we can see a part of the test bench where are located the hydraulic cylinders, the left draw is on extended position, which means the cylinder is in his maximum range of measurement of 300mm, and on the right position is on pick-up position, which means the measurement distance is 0mm.

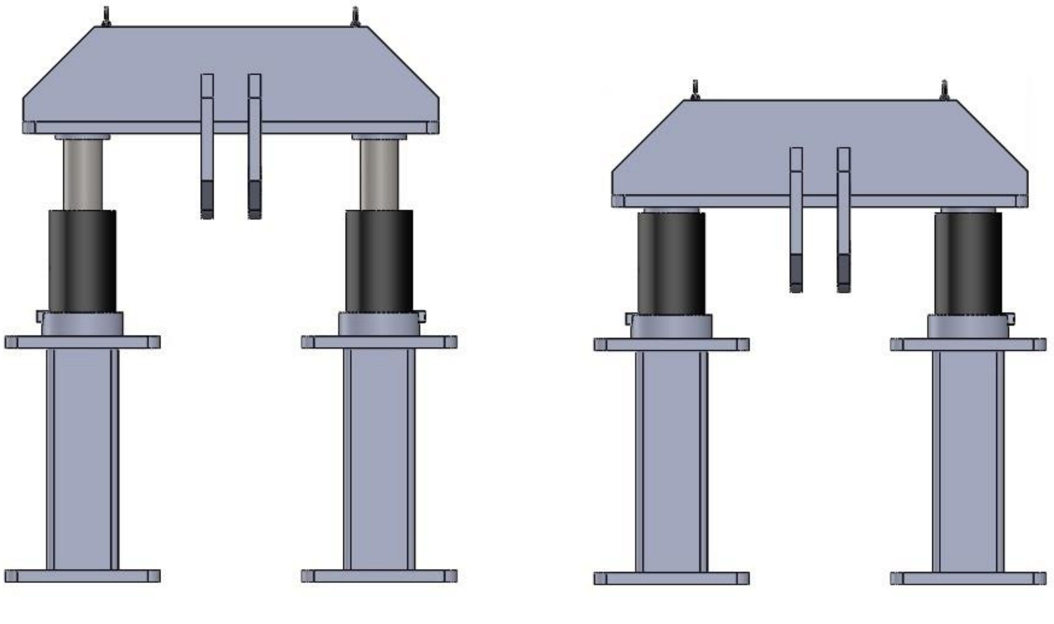

Figure 5.2 Extended and pick up position of the test bench

As the positioning of the cylinder is not easy due the form of the bench and cylinders, we cannot put it directly on the hydraulic cylinder. The main idea is to install it on the easiest way possible and in a form where the devices can be removed quickly. The final position of the linear position transducer will be parallel to the hydraulic cylinder, positioning the head pivoting of the linear position transducer directly to the upper part of the frame as we can see on the figure 5.4 and the other part will be located directly to the part of the frame which does not have movement because is the foot of the frame, as is shown on the figure 5.3.

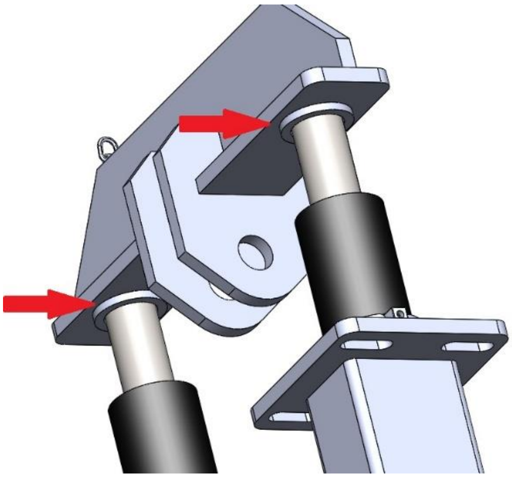

Figure 5.4 Upper part subjection

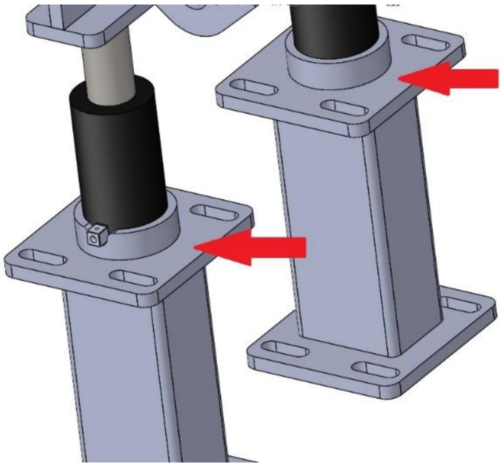

Figure 5.3 Bottom part subjection

There are many ways to fix the measurement cylinder to the bench, such as screws, magnets, welding some parts… The idea is to do this as easy practical and fast as it is possible. With these criteria, the welding and screw fix is totally discarded because it means the mechanical implantation will take time and must be very accurate because the measurement must be linear, cannot have degrees of deviation.

A really fast and easy way to implant the cylinder is with magnets, only needs to do eight pieces (two for each cylinder) which will be screwed directly to the linear position transducer and when all this part will be together will be positioned directly on the test bench with the magnets as it shown at the figure 5.5, doing the implantation fast and easy, also will allow to move the position of the cylinder just in case we want to change the place, moreover the positioning on the right position is really easy with a leveler.

Note, the measurement cylinders are generics, they do not correspond to the real and final ones.

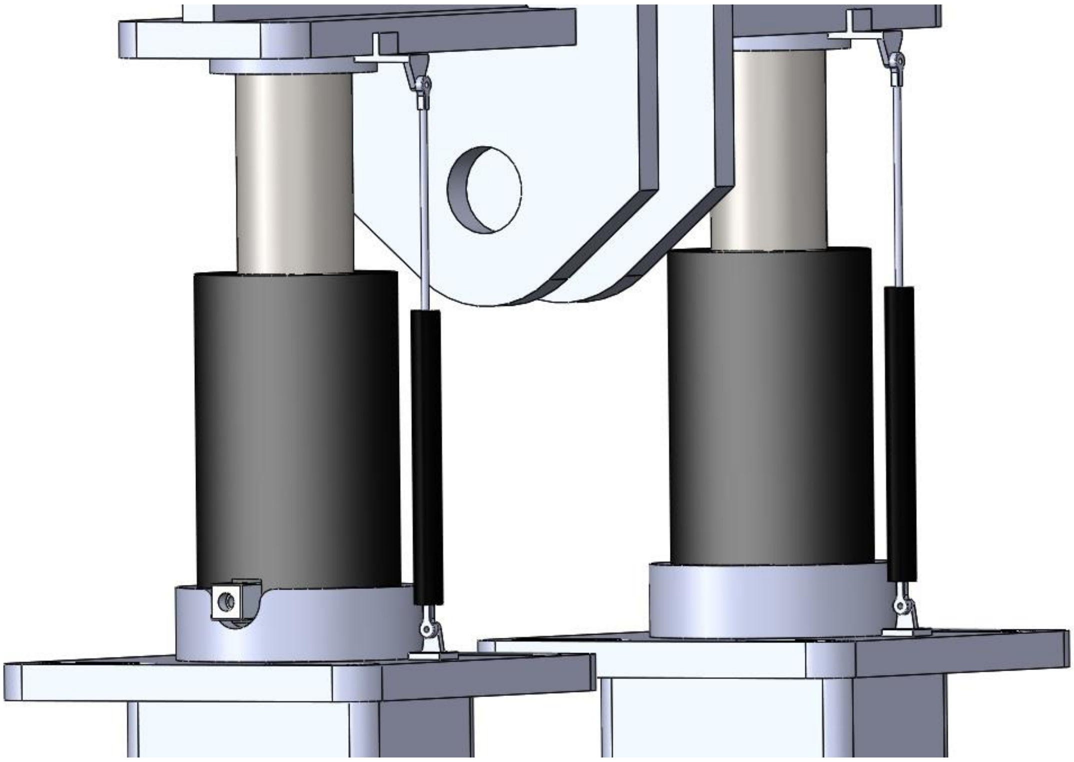

Figure 5.5 Positioning of the linear position transducer

The distance between the external edge of the immobile frame part and the bottom bracket is 300mm and 60mm respectively as it is shown at the figure below.

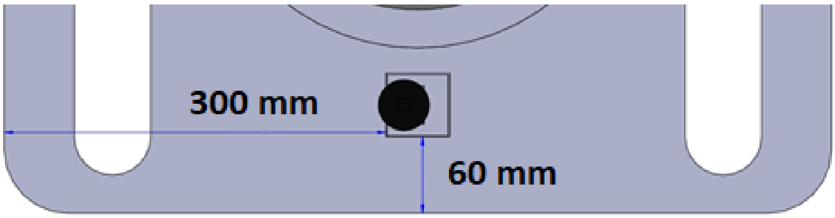

Figure 5.6 Distance on the bottom part of the frame

The designed pieces to implant the linear position transducer on the test bench are two as we can see on the figure 5.7. One is the bottom bracket where the head pivoting will be screwed and the other is upper bracket which will be screwed to the head pivoting of the linear position transducer too. The figure 5.8 is the detail how will implant the neodymium magnets on the pieces, those will be 20mm diameter and 5mm thick. For more information about the designed pieces look at in PLANES document.

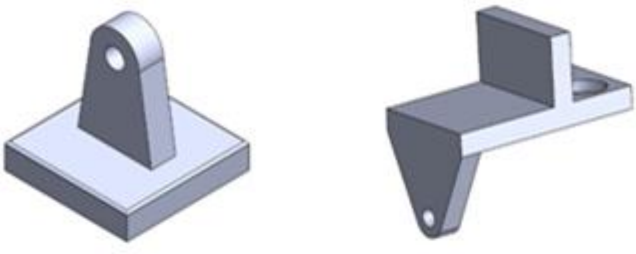

Figure 5.7 Designed pieces

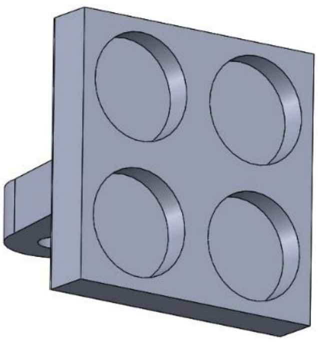

Figure 5.8 Detail Picture. Space to the neodymium magnets

5.5.3. Frame measurement.

To measure the frame will follow the same method done to implant the linear position transducer on the hydraulic cylinder. In this case but, the bottom bracket will be screwed on the floor because we need to fix it but here the magnets are not useful. It means the designed tool has to have a small variation. The holes for the location of the magnets were deleted and 4 through-holes of 6mm diameter are done instead as we can see on the picture below. For the upper bracket will use the same design of the hydraulic cylinders because those fit also here.

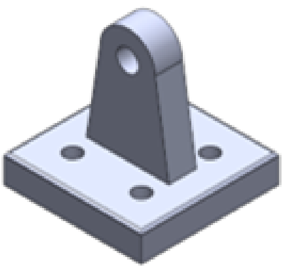

Figure 5.9 Screwed bottom bracket

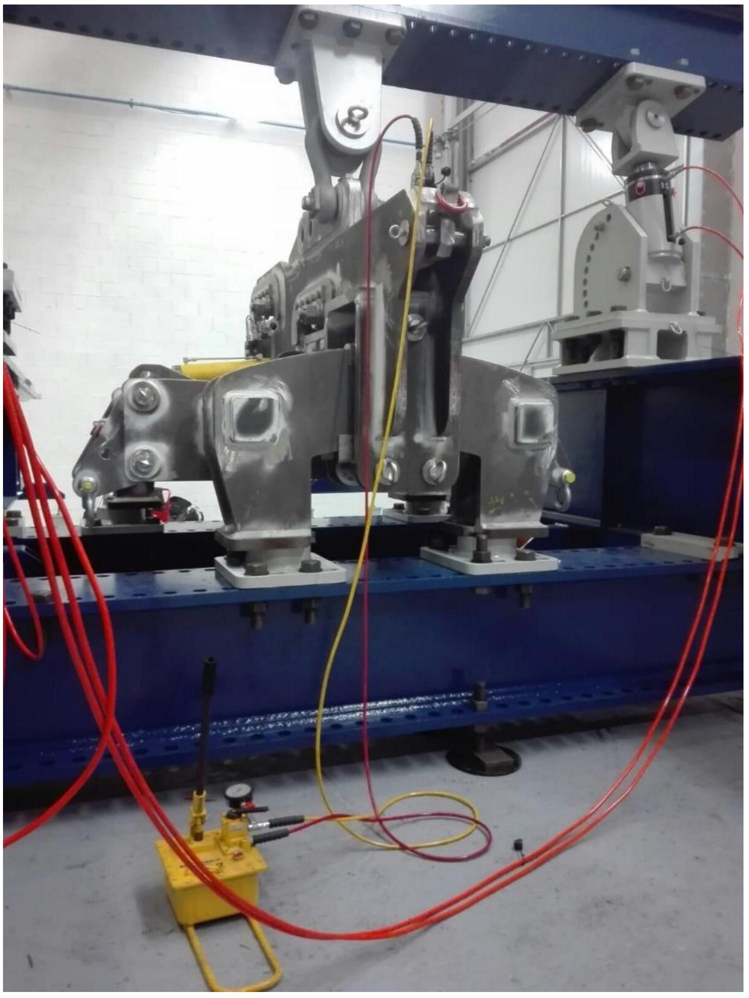

Figure 5.10 Test Bench

On the upper picture, we can see the frame of the test bench with a tool that is being tested (this tool is not the designed for the project). The frame is the part in color blue and the tool is the grey one. The idea is to locate the linear position transducer on the frame of the test bench to see the possible deformation. As it mentioned before these sensors need two adaptors to be mounted on the frame. The design for this project is shown below.

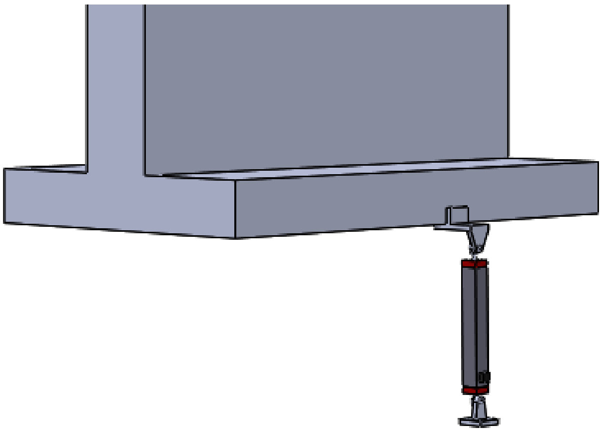

Figure 5.11 Monitoring frame bench

The positioning of the four linear position transducer will be as it shown at the picture below, two on the place as it shown and other two at the back part which is the same (the test bench is symmetrical). The distance between the linear position transduces will be 6 meters.

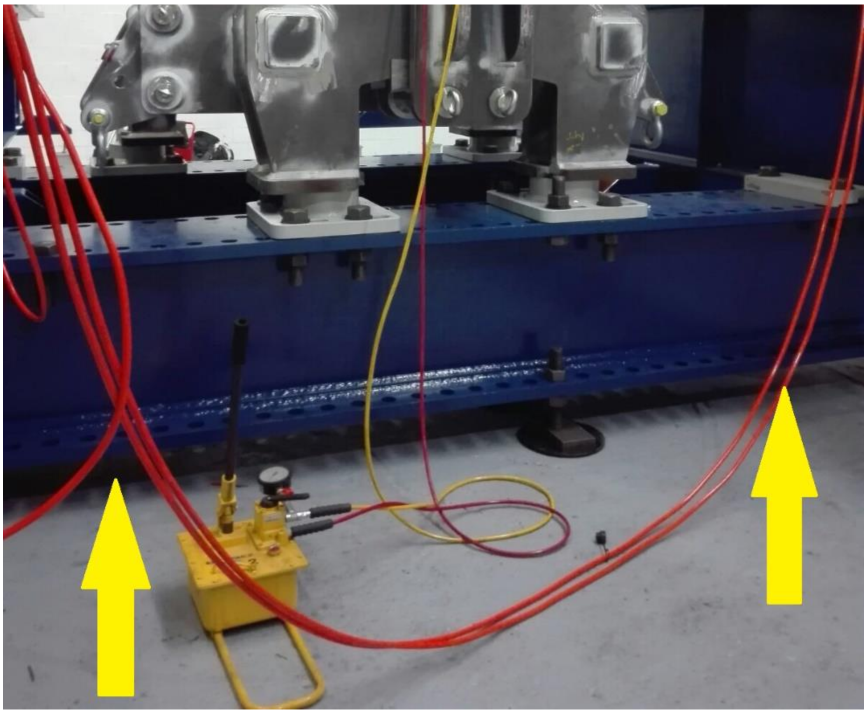

Figure 5.12 Location of the position transducer

5.5.4. Pressure measurement.

There are couple ways to measure the cylinder pression. One which is direct is to do a drill on the cylinder shirt and machine a thread, but this is not recommended because if there are some problems with it, all the times that is a necessity to change it either for damage or for maintenance all the hydraulic liquid will go out and if some day it is decided to remove the sensor the cylinder will have a hole where the pression can go out.

Other solution is to put the sensor on the output of the distributor, but we have to take in account that after that there is a hydraulic hose where we can lose pression due a damage of the hose or due to the length.

The final solution was to put the pressure sensor directly to the entrance of the cylinder because here it exists a connector which is screwed into the shirt of the cylinder and have a fast connector for the hose as we can see on the picture below.

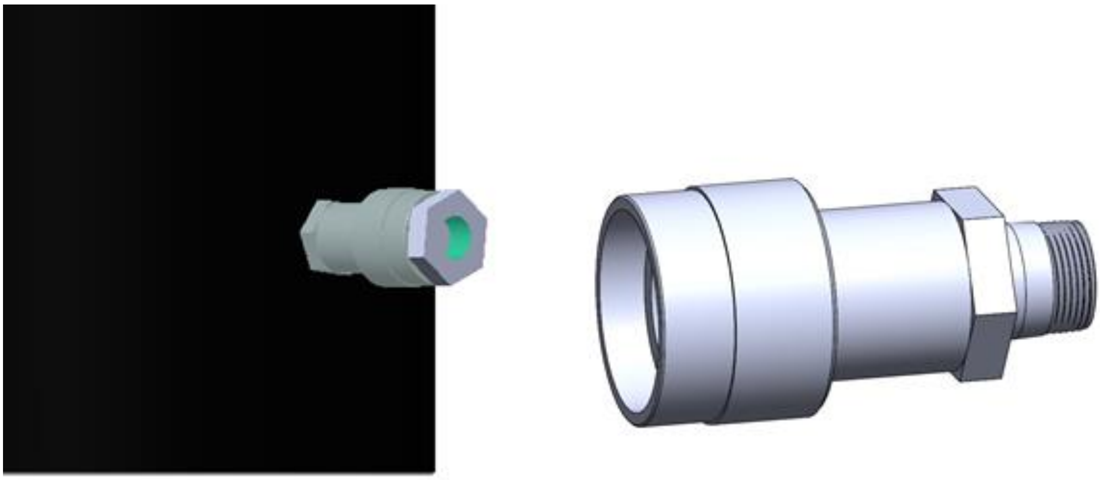

Figure 5.13 Detail of the fast connector of the hose

As we can see the right part of the connector is where is screwed to the shirt of the cylinder, and the other part is where is the fast connector of the hose. Here the pression will be the same of the interior of the cylinder and the loses will be practically null.

To do the measurement in this point we need put the adaptor between the connector and the cylinder. To do this we designed this adaptor as you can see on the picture below.

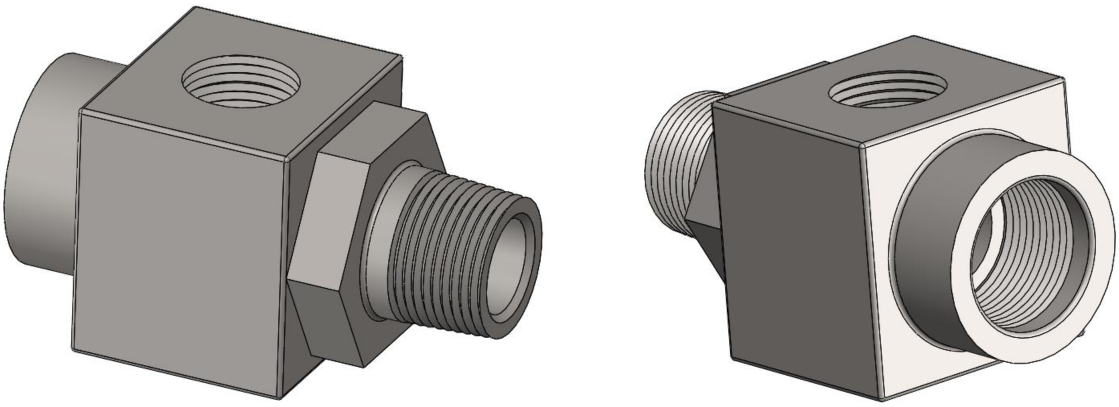

Figure 5.14 Detail of the designed adaptor

This adaptor will be screwed directly to the shirt of the cylinder instead of the connector, then the pressure sensor will be screwed on it at the top of the adaptor as it can be seen on the picture. The other part of the adaptor is where the old connector will be screwed. The thread of the sensor is G 1/4’’ and the thread of the fast connector and the adaptor are G 1/2’’.

With this we will able to know the pressure of each cylinder in real time. Moreover, there aren’t important changes, doing if one day the equipment will be removed the cylinder will remain as the beginning with no changes.

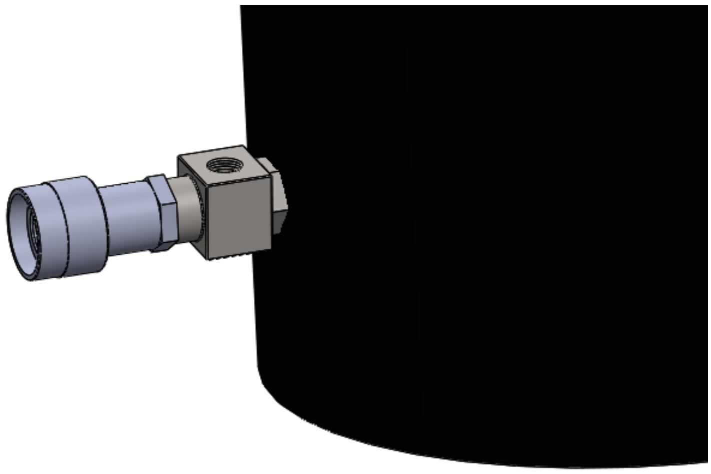

Figure 5.15 Final mounting on the cylinder

5.5.5. Electrical connections.

A small circuit has to be done to do the power supply of the devices. The computer does not have problem because it goes directly to the 220V. The same happens with the DAQ, this is powered by USB with the help of the computer.

The sensors are the ones who need the specific power supply, those are powered by 24 VDC. Due this a transformer is needed to change form 220 V of altern current to 24 V of direct current. The sensors will be connected in parallel and as they need only a bit of power supply only one transformer of 220V to 24 VDC is needed. This transformer is directly connected to 220V and the outputs are directly of 24VDC.

The connections will be done as we can see on the diagram below:

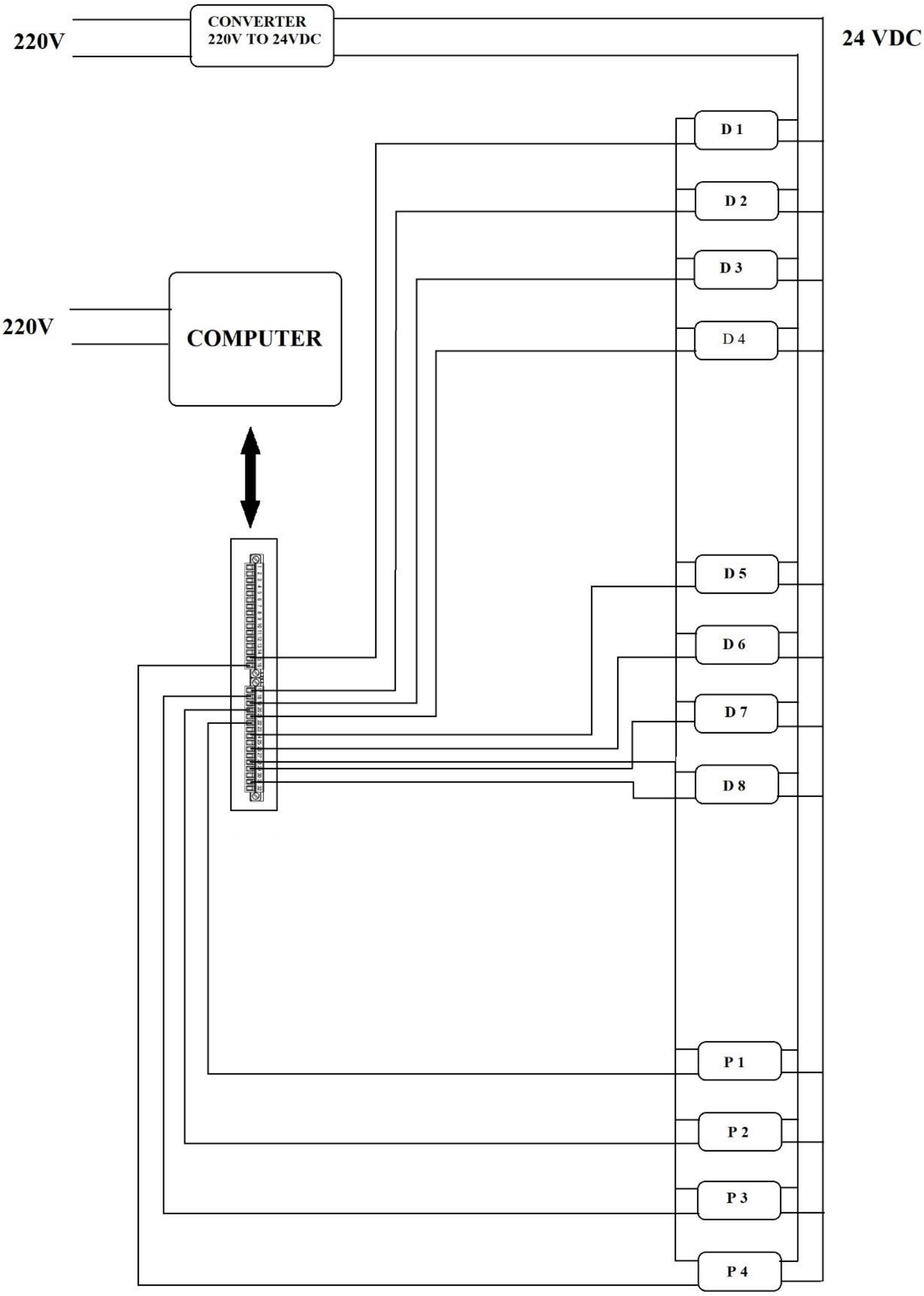

Figure 5.16 Electrical connections

5.5.6. Program of LabVIEW

This program is graphical, means there is not the necessity of write down a code as the other data acquisition systems. A serie of small icons does the function instead of the code and each one has one concrete function. The LabVIEW program has two screens, the front panel and the block diagram where all the front panel objects appear as terminals on the block diagram, that means each icon has his own appearance on the front panel.

The DAQ USB6210 has 16 analog inputs, for the project only 12 are used. Next is shown the pins used with his AI (analog input) associated.

PRESSURE SENSOR	
CHANNEL	PIN
AI 8	16
AI 9	18
AI 10	20
AI 11	22

LINEAR POSITION 100	
CHANNEL	PIN
AI 0	15
AI 1	17
AI 2	19
AI 3	21

LINEAR POSITION 300	
CHANNEL	PIN
AI 4	24
AI 5	26
AI 6	29
AI 7	31

Table 5.1 DAQ Inputs

On the next pages are shown the Front panel, which is the first one, and the block diagram which is the second one.

To begin with the explanation will do the front panel.

At the upper left side are four parameters that you can readjust quickly, they are the cutting frequency, sampling rate, number of samples and average samples. With this you can adjust the velocity of acquisition data and the number of samples you want to do per second. The more samples per second the more accurate will be the acquisition data, but you have to put a velocity according the equipment you have. In this case the important one for our project is the frequency, and was 1KHz enough samples for the acquisition we are looking for, the other parameters are by default. A stop button is also available, this stops all the program instantly if you press it.

At the top of the picture appears four distance sensors in form of visual indicators, they also have the numerical indicators too to see it more accurate. Those ones are for the distance sensors of 100mm.

The indicators who appears at the lower part of the picture correspond to the distance sensors of 300 mm and is the same as the 100 ones, a visual indicator and numeric ones but here is the difference between the other, those ones will be represented on the graphs shown on the front panel too.

For the pressure is the same method, visual and numerical indicators and the results are shown on the front panel, moreover these sensors also have the representation with graphs 8, 9,10 and 11.

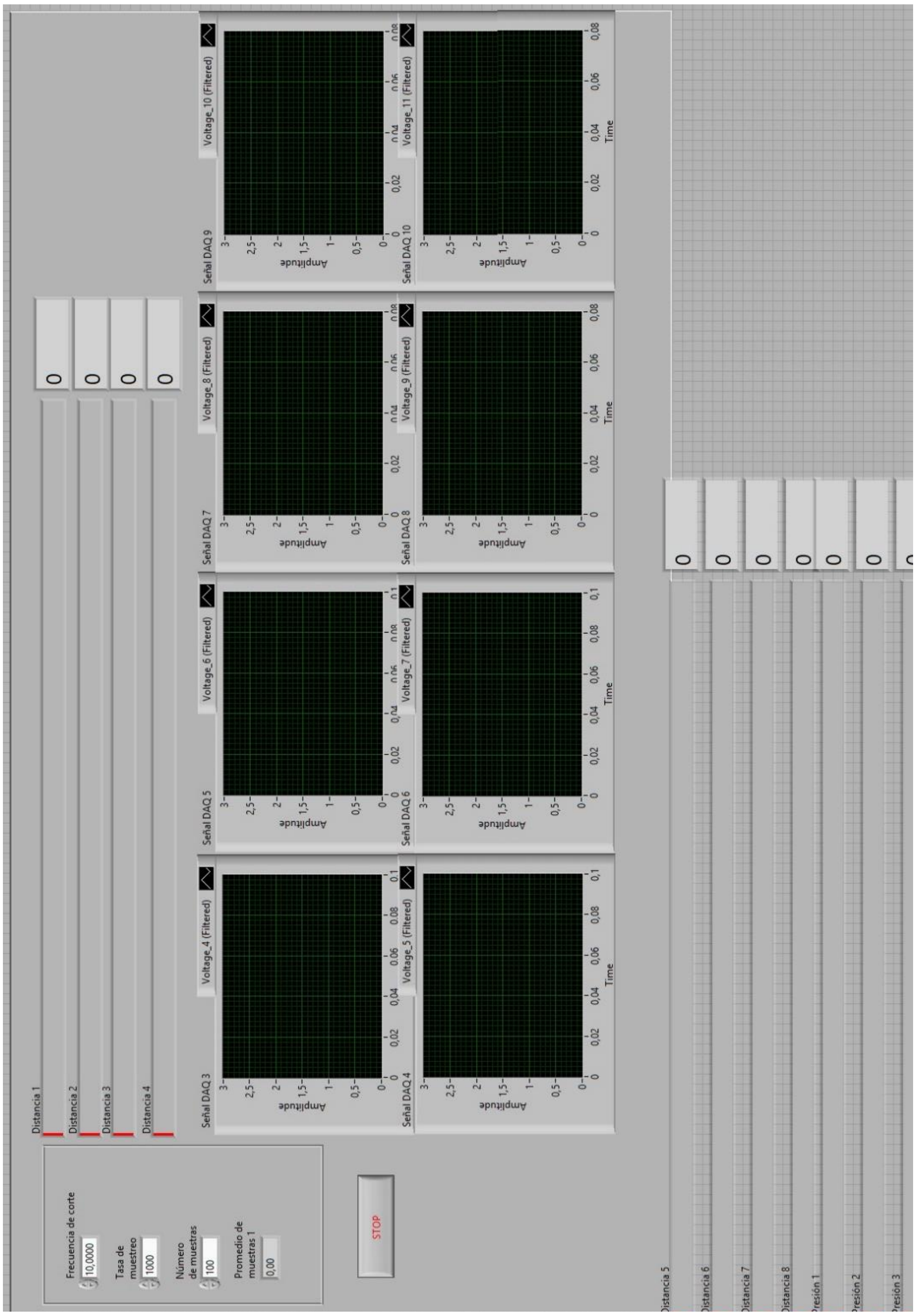

Figure 5.17 Front panel

For the block diagram, we can say that this is the code itself, but as we mentioned before is graphical, with block diagrams that you must join though cables.

The first part of the program is located on the left and are three Arrays in color orange. It seems to be a table and certainly it is. Here are the values of the sensors, the distance-voltage measured previously and the pressure-voltage too. (remember still waiting for the results, for this the voltage box are empty)

This information is crucial to the DAQ, because with this the device can interpret the data acquired and then it does interpolations trough Spline with the values previously written. Doing this the DAQ can interpret all the voltages and give us a value in form, in this case in mm.

The next item is the DAQ itself, this is the heart of the program as is shown on the picture below.

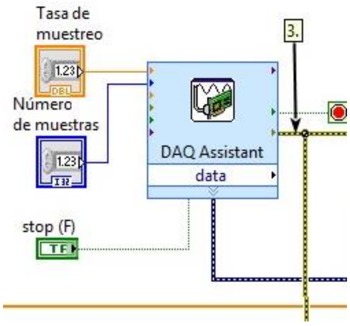

Figure 5.18 DAQ program detail

Here is where all the inputs of the DAQ are selected, with this you can communicate with the DAQ and program it depending the necessity. The upper left icon is the sample rate, the middle one is the number of samples and to finish the stop button explained before. All the selected AI’s come from here but they do not appear on the block diagram is something internal. The below blue wire is where all the signals that the DAQ has received and interpreted but processed, it means this is an outlet ready do connect to graphs or indicators (fists are few things to do) to see the results.

Then the next step is to separate those signals one by one, as we have twelve sensors we want to see all of them separately. On the program is the icon below.

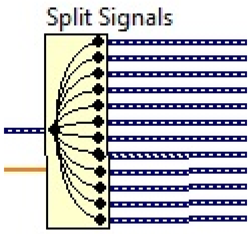

Figure 5.19 Split signals program detail

Once the signals are separated they pass through the filters because when you do an acquisition data always there is noise and if you do not pass it through it the result is not accurate. Then the ones from the linear position transducer of 100 mm goes directly to the interpolation mentioned before, here the signal is a voltage and with the help of this this voltage becomes to a numerical data that we can use.

The other ones that are the pressure and the linear position transducer of 300mm do the same, pass through the interpolation to convert the data but, as here we want to see graphs those are added. The final step for all the signals are to finish on the visual indicator.

On the next page is shown all the program.

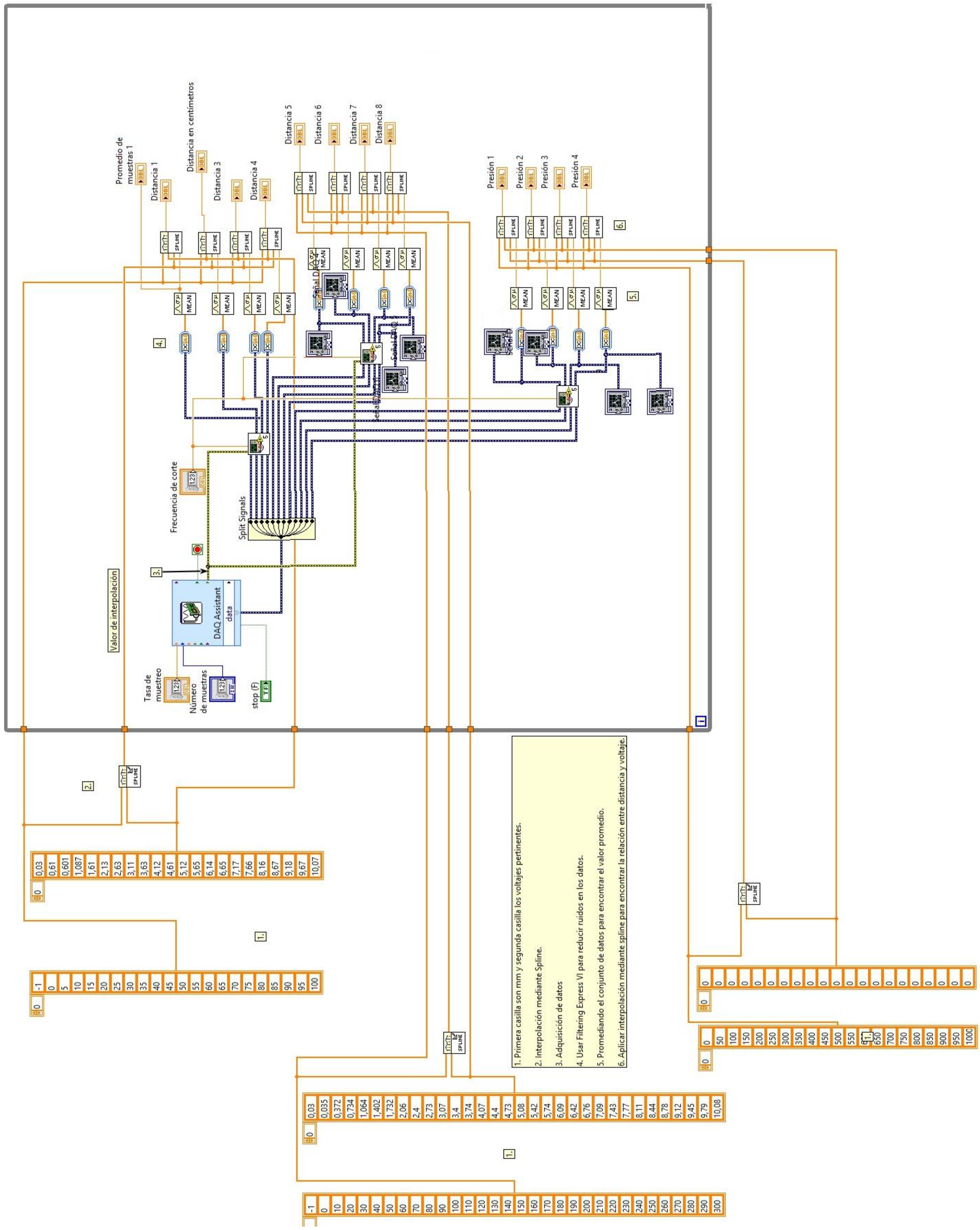

Figure 5.20 Block diagram

6. Real test

6.1. Arming devices

Before send the equipment to the installation of Kimua the devices and the portable box were armed on the garage in Barcelona. The sensors are connected by wires from the bench to the portable box where is located the DAQ, power supply and the computer. They want the equipment removable so there is a need to put connectors between the wires. First the cable work was done. To do it twelve hoses of ten meters were cut, the reason why is because they want to put the equipment into a safe distance from the test bench. As it mentioned before each group of hoses were marked by colors blue, red and yellow as we can see on the picture below.

Figure 6.1 Sensor wires

Once that was finished the connectors were mounted on the hoses, one edge with the connector DIN43650 C to plug the sensors and the other edge with the M12 4 pin male to do the plug and unplug easier.

The other part of the wires work was to do the part which goes from the M12 4 pin female that will be located fix on the portable box to the entrance of the DAQ and power supply as it can be seen on the next picture.

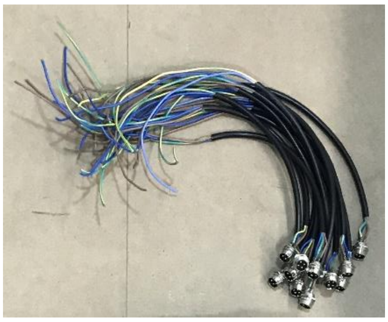

Figure 6.3 M12 Connectors

Figure 6.2 Welding cable work

The next stage was the modification of the portable box because it comes without any sleeve. The bottom space was used to do the sleeves to storage the equipment. Three were done, one for each group of sensors with their correspondent wires. Moreover, on the top part of the box a cover was covered to have the possibility to put the computer on the part above and have the possibility of working without the necessity of mounting the attached table. The differences between the original box and the modified one are shown below.

Figure 6.5 Modified storage box

Figure 6.4 original storage box

Next was the calibration of the sensors. We knew the range of measurement which goes from 0 to 103 mm and 0 to 303mm (one range from each sensor) but was not available a table or graphic which give us information between the relation of the distance done and the value of the output voltage.

The sensor was connected to the power supply and with the use of ruler and a caliper we measure when the linear position transducer started to give us an output signal. Then this point was marked as 0 and here from the totality of the measurement range was marked each 5 mm as it can be seen on the next picture.

Figure 6.6 Linear transducer position calibration

Once all the marks were done we measure each 5 mm and the value of the output was written down. This was done two times, one for each sensor and the finality was to obtain the next graphics with the help of Excel. For more information, consult ANNEX VIII. The importance of obtain this is crucial for this project because this data has to be inside the program of LabVIEW to do iterations and to know exactly for all the voltages the exact position where the linear position transducer is.

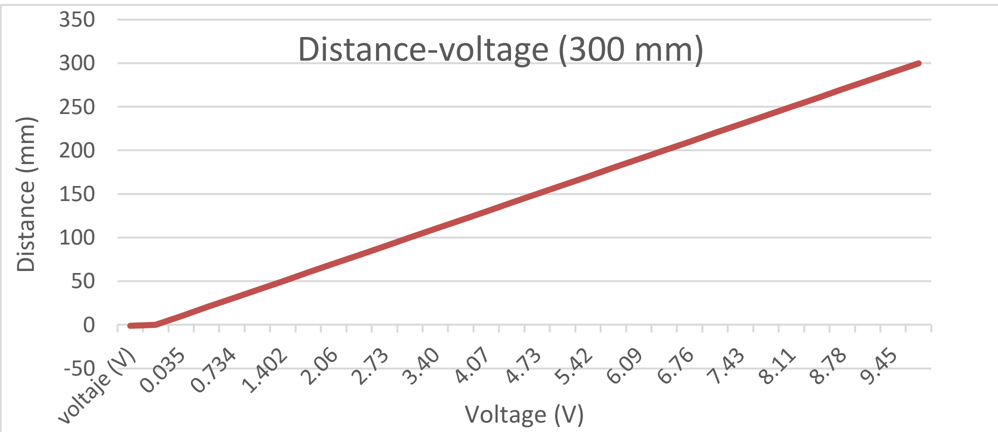

Figure 6.7 Relation distance-voltaje sensor 300mm

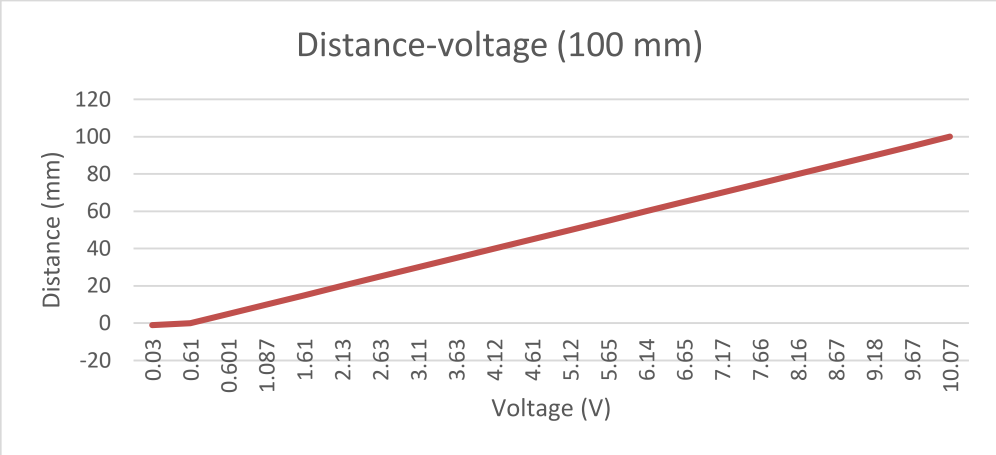

Figure 6.8 Relation distance-voltaje sensor 100mm

For the pressure sensors, something similar has to be done. The relation between the pressure and the output voltage is not given by the fabricant, then we have to calibrate it. In this case was not as easy as with the linear position transducer due the necessity of the pressure bomb and hydraulic systems. To test the pressure sensors, we have to mount them into the outlet of the pump, then give pressure to it and recompile the results for each pressure. The table is marked on the program and in the ANNEX VIII, but the results of the voltages are empty due this has to be done by the company of Kimua.

6.2. Arming test bench

The final step was to implant all the devices on the test bench. Due the delays on the load test and timetables of the company the equipment was send to the Vasc Country the first week of August to start doing tests on the time they have between projects. Some pictures of the test bench with the equipment are shown below.

Figure 6.9 Test bench

Figure 6.10 Test bench

Figure 6.11 Test bench with the equipment

NOTE: There is a difference between the first picture and the other ones from the test bench. This is due in which type of tool they have to test. Every tool has his own configurations and the test bench has to adapt to it. Moreover, they had paint the bench and the installations and the first picture is from before they did this.

The only test done nowadays was for the pressure sensor. As we can see on the picture below they install in on the input of one distributor and they give pressure and measure it. The results for the characteristics and the graphics are still waiting.

Figure 6.12 Test of the pressure sensor

7. Environmental study

This project it is about the implementation of some sensors on the test bench to monitor it. There are some different aspects which are consider in his project like the effects on the clime, impact on the quality of air, impact on the hydrology… which are reflected on the ANNEX IX. The final summary of this tables is shown at the end of this point.

With this small study, we can conclude that as the project will be done on the company KIMUA, a place which already exists, the impact will be practically non-existing. This project is based on the monitoring of one test bench to do different tests and see what is happening, so nothing new will be done, the project will take place in a controlled and safe place and is only a small variation on the bench test doing it more effective with the monitoring of itself.

The only change is the consumption of electricity of the devices, but as they are powered supplied by 24 VDC through a 220V transformer, the DAQ is USB powered by the computer and the computer itself is a small Laptop, we are talking about 750-1000W and less than 5A of consumption, this for a big company as Kimua is less than the 1/10 part of their daily consumption.

The sensors come from two ways, the pressure ones are from Catsensors [8] and the distance are from Encosolution [9], the DAQ comes from National instruments. All of them are big suppliers who have their own control and follow the law and rules on the environmental field. So, it is supposed the sensors and DAQ come from a controlled place.

We can conclude then that this project does not have a real repercussion on the environment because the only change is the electricity and we saw is a small consumption, which compared of the total consumption on the company is practically null.

IMPACT ACTIONS		OBSERVATION
CONSTRUCTION PHASE	material transport	In this phase have we can find contamination due the tranport of the devices, first to the garage where the devicer were manipulated and the final transport to the Kimua installations
	possible modifications	
	mounting devices	
OPERATION PHASE	system operation	Meanwhile the equipment is being used will consume electricity
	electricity consumption	

Table 7.1 Impact actions

ENVIRONMENTAL FACTOR		POSSIBLE IMPACT
NATURAL ENVIRONMENT	atmosphere	there is no impact
	floor	for the frame bench monitoring. Few drills has to be done
	water	there is no impact
	flora	there is no impact
	wildlife	there is no impact
	perceptual medium	there is no impact
SOCIO-ECONOMIC ENVIRONMENT	territory use	there is no impact
	cultural	there is no impact
	infraestructure	there is no impact
	humans	there is no impact
	economy and poblation	there is no impact

Table 7.2 Environmental factors

8. Project planning and deviations.

In this point will see all the projects planning done on this project with the differences and explaining the deviations of itself.

8.1. Project planning.

To ensure a reliable anticipation a project planning was made to follow a calendar and to know which tasks we must do in all moments. The main tasks with the sub tasks associated with this project and the Gant diagram are shown below.

		Modo de	Nombre de tarea	Duración	Comienzo	Fin	Predecesoras	Nombres de lc
1			START	0 horas	mar 01/11/16	mar 01/11/16		
2			**1.PROBLEM IDENTIFICATION**	**18,5 días**	**mar 01/11/16**	**vie 25/11/16**		
3			1.1 Object	9 horas	mar 01/11/16	jue 03/11/16	1	Engineer
4			1.2 Background	29 horas	lun 14/11/16	mié 23/11/16	3	Engineer
5			1.3 Information requirments	28 horas	jue 03/11/16	lun 14/11/16	3	Engineer
6			1.4 Scope	8 horas	mié 23/11/16	vie 25/11/16	5;4	Engineer
7			**2.OBJECTIVES AND TECHNICAL SPECIFICATIONS**	**4,5 días**	**vie 25/11/16**	**jue 01/12/16**		
8			2.1 Define objectives	9 horas	vie 25/11/16	mar 29/11/16	6	Engineer
9			2.2 Technical specifications	18 horas	vie 25/11/16	jue 01/12/16	6	Engineer
10			**3.POSSIBLE ALTERNATIVES**	**9,5 días**	**vie 02/12/16**	**jue 15/12/16**		
11			3.1 Search for alternatives	11 horas	vie 02/12/16	mar 06/12/16	9	Engineer
12			3.2 Study of alternatives	27 horas	mar 06/12/16	jue 15/12/16	11	Engineer
13			DOCUMENT REVISION	2 horas	jue 15/12/16	jue 15/12/16	10	Engineer
14			**4.ANALYSIS VIABILITY**	**12 días**	**jue 15/12/16**	**lun 02/01/17**		
15			4.1 Selection of most accurate alternative	9 horas	jue 15/12/16	lun 19/12/16	12	Engineer
16			4.2 Technical viability	39 horas	lun 19/12/16	lun 02/01/17	15	Engineer
17			4.3 Economic viability	34 horas	lun 19/12/16	vie 30/12/16	15	Engineer
18			4.4 Environmenal viability	34 horas	lun 19/12/16	vie 30/12/16	15	Engineer
19			**5.PROJECT PLANNING**	**4,75 días**	**vie 30/12/16**	**jue 05/01/17**		
20			5.1 Appoint general tasks	4 horas	vie 30/12/16	lun 02/01/17	18	Engineer
21			5.2 Establish duration tasks	5 horas	lun 02/01/17	mar 03/01/17	20	Engineer
22			5.3 Elaboration of MS-Project	10 horas	mar 03/01/17	jue 05/01/17	21	Engineer
23			**6.PROGRAMMING**	**21,25 días**	**vie 06/01/17**	**lun 06/02/17**		
24			6.1 Learning Phyton	40 horas	vie 06/01/17	jue 19/01/17	22	Engineer
25			6.2 Do small programs and tests	45 horas	vie 20/01/17	lun 06/02/17	24	Engineer
26			**7.BUDGET**	**3,25 días**	**lun 06/02/17**	**jue 09/02/17**		
27			7.1 Price list	6 horas	lun 06/02/17	mar 07/02/17	25	Engineer
28			7.2 Project budget	7 horas	mar 07/02/17	jue 09/02/17	27	Engineer
29			8.DELIVERY DOCUMENT	0 días	jue 09/02/17	jue 09/02/17	28	
30			9.DO CORRECTIONS ON THE DOCUMENT	20 horas	jue 09/02/17	jue 16/02/17	29	

Table 8.1 Project planning (part 1)

31	**10.PROTOTYPE 1**	**6,75 días**	**vie 17/02/17**	**lun 27/02/17**		
32	10.1 Install ADC converter	4 horas	vie 17/02/17	vie 17/02/17	30	Engineer
33	10.2 Program ADC	8 horas	lun 20/02/17	mar 21/02/17	32	Engineer
34	10.3 Do acquisition data	15 horas	mié 22/02/17	lun 27/02/17	33	Engineer
35	**11. TECHNICAL VIABILITY DAQ**	**6,25 días**	**lun 27/02/17**	**mar 07/03/17**		
36	11.1 Research DAQ information	17 horas	lun 27/02/17	vie 03/03/17	34	Engineer
37	11.2 Selection most accurate DAQ	8 horas	lun 06/03/17	mar 07/03/17	36	Engineer
38	**12. TECHNICAL VIABILITY SENSORS**	**6,25 días**	**mié 08/03/17**	**jue 16/03/17**		
39	12.1 Research new distance sensors	15 horas	mié 08/03/17	lun 13/03/17	37	Engineer
40	12.2 Research new pressure sensors	10 horas	lun 13/03/17	jue 16/03/17	39	Engineer
41	**13. LEARN LABVIEW**	**17,75 días**	**jue 16/03/17**	**lun 10/04/17**		
42	13.1 See tutorial videos on NI	27 horas	jue 16/03/17	vie 24/03/17	40	Engineer
43	13.2 See tutorial videos on internet	22 horas	lun 27/03/17	lun 03/04/17	42	Engineer
44	13.3 Download exercices and do them	22 horas	lun 03/04/17	lun 10/04/17	43	Engineer
45	**14. FIND PROVIDERS**	**16,25 días**	**mar 11/04/17**	**mié 03/05/17**		
46	14.1 Call providers	5 horas	mar 11/04/17	mié 12/04/17	44	Engineer
47	14.2 Find best offer	13 días	mié 12/04/17	lun 01/05/17	46	
48	14.3 Choose provider	5 horas	lun 01/05/17	mar 02/05/17	47	Engineer
49	14.4 Meeting with provider	3 horas	mar 02/05/17	mié 03/05/17	48	Engineer
50	**15. START REDACT MEMORY**	10 días	mié 03/05/17	mié 17/05/17	49	Engineer
51	**16. ASK FOR MATERIAL**	**17,5 días**	**mié 17/05/17**	**vie 09/06/17**		
52	16.1 Call providers	2 horas	mié 17/05/17	mié 17/05/17	50	Engineer
53	16.2 Pay and wait for the devices	17 días	mié 17/05/17	vie 09/06/17	52	
54	**17. PROTOTYPE 2**	**16,25 días**	**vie 09/06/17**	**lun 03/07/17**		
55	17.1 Install Software on the computer	3 horas	vie 09/06/17	lun 12/06/17	53	Engineer
56	17.2 Install software DAQ	2 horas	lun 12/06/17	lun 12/06/17	55	Engineer
57	17.3 Do the program	50 horas	mar 13/06/17	jue 29/06/17	56	Engineer
58	17.4 Do sensors interact with DAQ and computer	10 horas	jue 29/06/17	lun 03/07/17	57	Engineer
59	**18. DO REAL TEST**	**8 días**	**mar 04/07/17**	**jue 13/07/17**		
60	18.1 Install all the devices	10 horas	mar 04/07/17	jue 06/07/17	58	Engineer
61	18.2 Run the program and do all works	2 horas	jue 06/07/17	jue 06/07/17	60	Engineer
62	18.3 Do the load tests	20 horas	vie 07/07/17	jue 13/07/17	61	Engineer
63	**19. RECOMPILATION DATA**	**4,25 días**	**vie 14/07/17**	**jue 20/07/17**		
64	19.1 Test conclusions	2 horas	vie 14/07/17	vie 14/07/17	62	Engineer
65	19.2 Finish redact memory	15 horas	vie 14/07/17	jue 20/07/17	64	Engineer
66	**20. DELIVERY DOCUMENT (FINISH)**	0 días	mié 27/09/17	mié 27/09/17	65	

Table 8.2 Project planning (part 2)

Nombre de tarea	Duración	Comienzo	Fin
START	0 horas	mar 01/11/16	mar 01/11/16
1.PROBLEM IDENTIFICATI	**18,5 días**	**mar 01/11/16**	**vie 25/11/16**
1.1 Object	9 horas	mar 01/11/16	jue 03/11/16
1.2 Background	29 horas	lun 14/11/16	mié 23/11/16
1.3 Information requir	28 horas	jue 03/11/16	lun 14/11/16
1.4 Scope	8 horas	mié 23/11/16	vie 25/11/16
2.OBJECTIVES AND TECHI	**4,5 días**	**vie 25/11/16**	**jue 01/12/16**
2.1 Define objectives	9 horas	vie 25/11/16	mar 29/11/16
2.2 Technical specifica	18 horas	vie 25/11/16	jue 01/12/16
3.POSSIBLE ALTERNATIVE	**9,5 días**	**vie 02/12/16**	**jue 15/12/16**
3.1 Search for alternat	11 horas	vie 02/12/16	mar 06/12/16
3.2 Study of alternativ	27 horas	mar 06/12/16	jue 15/12/16
DOCUMENT REVISION	2 horas	jue 15/12/16	jue 15/12/16
4.ANALYSIS VIABILITY	**11,5 días**	**jue 15/12/16**	**vie 30/12/16**
4.1 Selection of most a	9 horas	jue 15/12/16	lun 19/12/16
4.2 Technical viability	37 horas	lun 19/12/16	vie 30/12/16
4.3 Economic viability	34 horas	lun 19/12/16	vie 30/12/16
4.4 Environmenal viab	34 horas	lun 19/12/16	vie 30/12/16
5.PROJECT PLANNING	**4,75 días**	**vie 30/12/16**	**jue 05/01/17**
5.1 Appoint general ta	4 horas	vie 30/12/16	lun 02/01/17
5.2 Establish duration	5 horas	lun 02/01/17	mar 03/01/17
5.3 Elaboration of MS-	10 horas	mar 03/01/17	jue 05/01/17
6.PROGRAMMING	**21,25 días**	**vie 06/01/17**	**lun 06/02/17**
6.1 Learning Phyton	40 horas	vie 06/01/17	jue 19/01/17
6.2 Do small programs	45 horas	vie 20/01/17	lun 06/02/17
7.BUDGET	**3,25 días**	**lun 06/02/17**	**jue 09/02/17**
7.1 Price list	6 horas	lun 06/02/17	mar 07/02/17
7.2 Project budget	7 horas	mar 07/02/17	jue 09/02/17
8.DELIVERY DOCUMENT	0 días	jue 09/02/17	jue 09/02/17
9.DO CORRECTIONS ON T	22 horas	jue 09/02/17	jue 16/02/17
10.PROTOTYPE 1	**6,75 días**	**vie 17/02/17**	**lun 27/02/17**
10.1 Install ADC conve	4 horas	vie 17/02/17	vie 17/02/17
10.2 Program ADC	8 horas	lun 20/02/17	mar 21/02/17
10.3 Do acquisition dat	15 horas	mié 22/02/17	lun 27/02/17
11. TECHNICAL VIABILITY	**6,25 días**	**lun 27/02/17**	**mar 07/03/17**

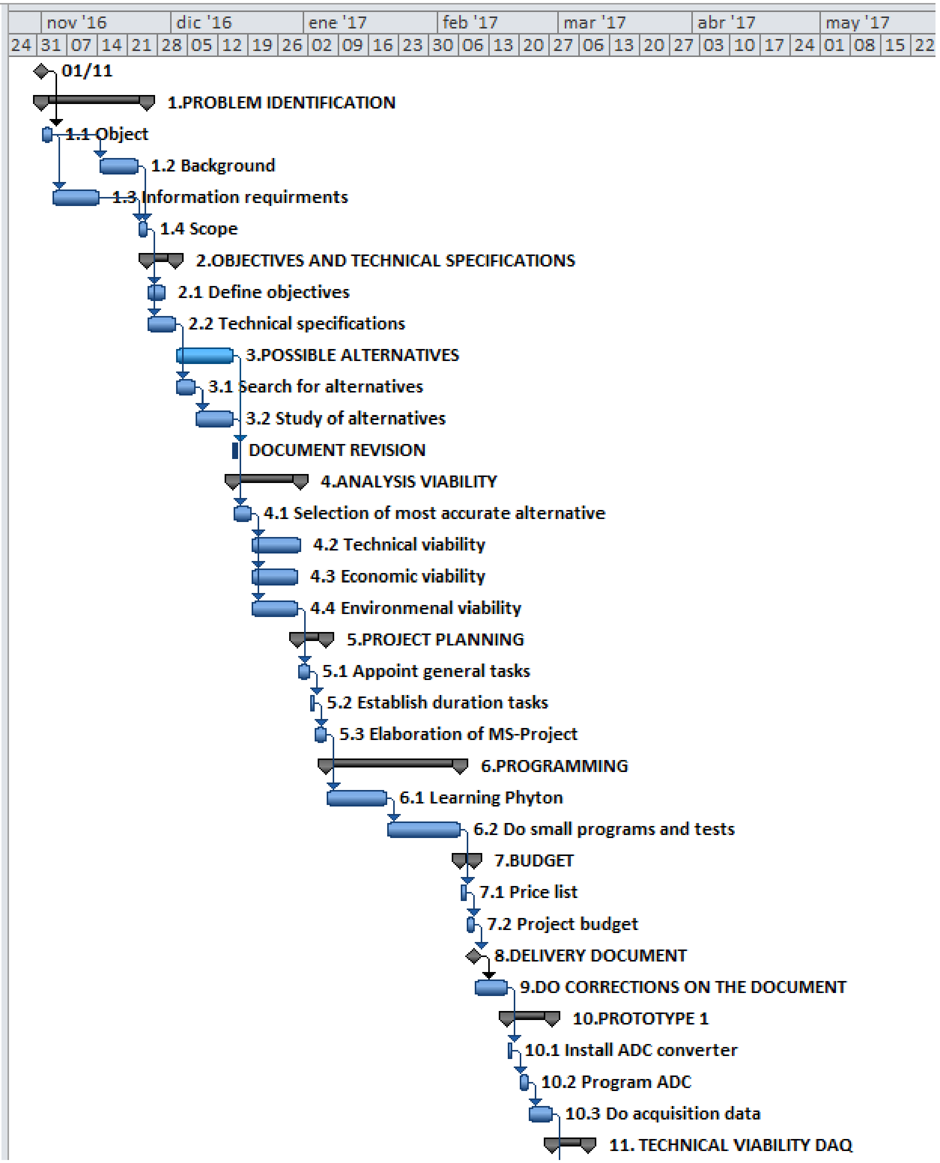

Figure 8.1 Gantt diagram (part 1)

Nombre de tarea	Duración	Comienzo	Fin
11. TECHNICAL VIABILITY	**6,25 días**	**lun 27/02/17**	**mar 07/03/17**
11.1 Research DAQ inf	17 horas	lun 27/02/17	vie 03/03/17
11.2 Selection most ac	8 horas	lun 06/03/17	mar 07/03/17
12. TECHNICAL VIABILITY	**6,25 días**	**mié 08/03/17**	**jue 16/03/17**
12.1 Research new dis	15 horas	mié 08/03/17	lun 13/03/17
12.2 Research new pre	10 horas	lun 13/03/17	jue 16/03/17
13. LEARN LABVIEW	**17,75 días**	**jue 16/03/17**	**lun 10/04/17**
13.1 See tutorial videc	27 horas	jue 16/03/17	vie 24/03/17
13.2 See tutorial videc	22 horas	lun 27/03/17	lun 03/04/17
13.3 Download exercic	22 horas	lun 03/04/17	lun 10/04/17
14. FIND PROVIDERS	**16,25 días**	**mar 11/04/17**	**mié 03/05/17**
14.1 Call providers	5 horas	mar 11/04/17	mié 12/04/17
14.2 Find best offer	13 días	mié 12/04/17	lun 01/05/17
14.3 Choose provider	5 horas	lun 01/05/17	mar 02/05/17
14.4 Meeting with pro	3 horas	mar 02/05/17	mié 03/05/17
15. START REDACT MEMC	10 días	mié 03/05/17	mié 17/05/17
16. ASK FOR MATERIAL	**17,5 días**	**mié 17/05/17**	**vie 09/06/17**
16.1 Call providers	2 horas	mié 17/05/17	mié 17/05/17
16.2 Pay and wait for t	17 días	mié 17/05/17	vie 09/06/17
17. PROTOTYPE 2	**16,25 días**	**vie 09/06/17**	**lun 03/07/17**
17.1 Install Software o	3 horas	vie 09/06/17	lun 12/06/17
17.2 Install software D	2 horas	lun 12/06/17	lun 12/06/17
17.3 Do the program	50 horas	mar 13/06/17	jue 29/06/17
17.4 Do sensors intera	10 horas	jue 29/06/17	lun 03/07/17
18. DO REAL TEST	**8 días**	**mar 04/07/17**	**jue 13/07/17**
18.1 Install all the devi	10 horas	mar 04/07/17	jue 06/07/17
18.2 Run the program a	2 horas	jue 06/07/17	jue 06/07/17
18.3 Do the load tests	20 horas	vie 07/07/17	jue 13/07/17
19. RECOMPILATION DAT	**4,25 días**	**vie 14/07/17**	**jue 20/07/17**
19.1 Test conclusions	2 horas	vie 14/07/17	vie 14/07/17
19.2 Finish redact mer	15 horas	vie 14/07/17	jue 20/07/17
20. DELIVERY DOCUMENT	0 días	mié 27/09/17	mié 27/09/17

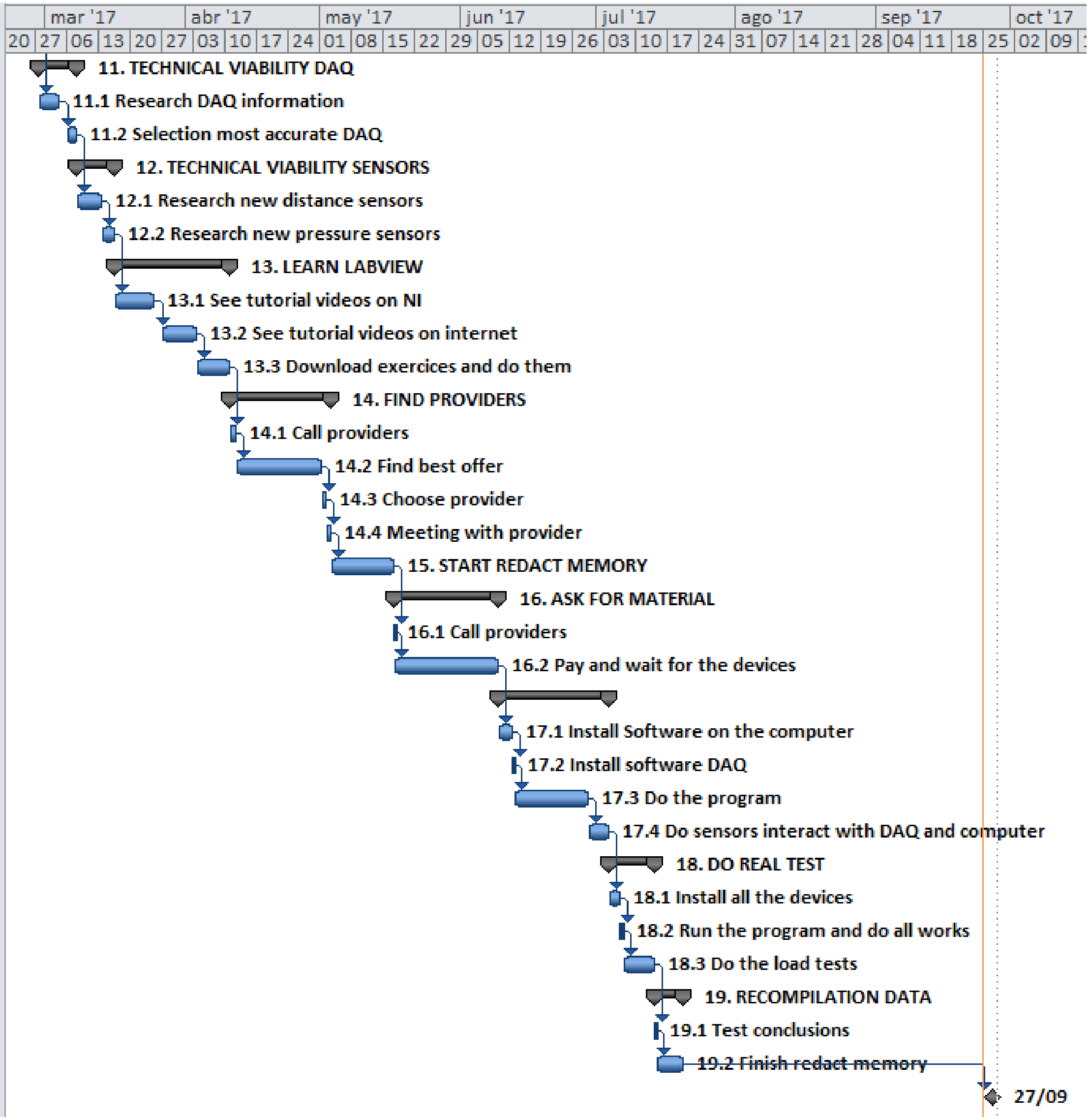

Figure 8.2 Gantt diagram (part 2)

8.2. Deviations.

In this point the deviations of the project will be shown. At the beginning of the project a planning was made to anticipate the tasks that should be done. As the project was progressing we realized the first planning was not enough and the correct one to achieve the project. Below is shown the first planning of the project.

		Modo de	Nombre de tarea	Duración	Comienzo	Fin	Predecesoras	Nombres de lc
1			START	0 horas	mar 01/11/16	mar 01/11/16		
2			**1.PROBLEM IDENTIFICATION**	**18,5 días**	**mar 01/11/16**	**vie 25/11/16**		
3			1.1 Object	9 horas	mar 01/11/16	jue 03/11/16	1	Engineer
4			1.2 Background	29 horas	lun 14/11/16	mié 23/11/16	3	Engineer
5			1.3 Information requirments	28 horas	jue 03/11/16	lun 14/11/16	3	Engineer
6			1.4 Scope	8 horas	mié 23/11/16	vie 25/11/16	5;4	Engineer
7			**2.OBJECTIVES AND TECHNICAL SPECIFICATIONS**	**4,5 días**	**vie 25/11/16**	**jue 01/12/16**		
8			2.1 Define objectives	9 horas	vie 25/11/16	mar 29/11/16	6	Engineer
9			2.2 Technical specifications	18 horas	vie 25/11/16	jue 01/12/16	6	Engineer
10			**3.POSSIBLE ALTERNATIVES**	**9,5 días**	**vie 02/12/16**	**jue 15/12/16**		
11			3.1 Search for alternatives	11 horas	vie 02/12/16	mar 06/12/16	9	Engineer
12			3.2 Study of alternatives	27 horas	mar 06/12/16	jue 15/12/16	11	Engineer
13			DOCUMENT REVISION	2 horas	jue 15/12/16	jue 15/12/16	10	Engineer
14			**4.ANALYSIS VIABILITY**	**12 días**	**jue 15/12/16**	**lun 02/01/17**		
15			4.1 Selection of most accurate alternative	9 horas	jue 15/12/16	lun 19/12/16	12	Engineer
16			4.2 Technical viability	39 horas	lun 19/12/16	lun 02/01/17	15	Engineer
17			4.3 Economic viability	34 horas	lun 19/12/16	vie 30/12/16	15	Engineer
18			4.4 Environmenal viability	34 horas	lun 19/12/16	vie 30/12/16	15	Engineer
19			**5.PROJECT PLANNING**	**4,75 días**	**vie 30/12/16**	**jue 05/01/17**		
20			5.1 Appoint general tasks	4 horas	vie 30/12/16	lun 02/01/17	18	Engineer
21			5.2 Establish duration tasks	5 horas	lun 02/01/17	mar 03/01/17	20	Engineer
22			5.3 Elaboration of MS-Project	10 horas	mar 03/01/17	jue 05/01/17	21	Engineer
23			**6.PROGRAMMING**	**21,25 días**	**vie 06/01/17**	**lun 06/02/17**		
24			6.1 Learning Phyton	40 horas	vie 06/01/17	jue 19/01/17	22	Engineer
25			6.2 Do small programs and tests	45 horas	vie 20/01/17	lun 06/02/17	24	Engineer
26			**7.BUDGET**	**3,25 días**	**lun 06/02/17**	**jue 09/02/17**		
27			7.1 Price list	6 horas	lun 06/02/17	mar 07/02/17	25	Engineer
28			7.2 Project budget	7 horas	mar 07/02/17	jue 09/02/17	27	Engineer
29			8.DELIVERY DOCUMENT	0 días	jue 09/02/17	jue 09/02/17	28	
30			9.DO CORRECTIONS ON THE DOCUMENT	20 horas	jue 09/02/17	jue 16/02/17	29	

Table 8.3 First project planning (part 1)

		Modo de	Nombre de tarea	Duración	Comienzo	Fin	Predecesoras	Nombres de los re
30			9.DO CORRECTIONS ON THE DOCUMENT	20 horas	jue 09/02/17	jue 16/02/17	29	
31			**10.DO PROTOTYPE 1**	**21,25 días**	**jue 16/02/17**	**vie 17/03/17**		
32			10.1 Do the progam	35 horas	jue 16/02/17	mié 01/03/17	30	Engineer
33			10.2 Do sensors interact	30 horas	mié 01/03/17	vie 10/03/17	32	Engineer
34			10.3 Do the test on the test bench	20 horas	vie 10/03/17	vie 17/03/17	33	Engineer
35			**11. TECHNICAL VIABILITY OTHER SENSORS**	**10,75 días**	**vie 17/03/17**	**lun 03/04/17**		
36			11.1 Research other sensors	35 horas	vie 17/03/17	jue 30/03/17	34	Engineer
37			11.2 Selection most accurate sensors	8 horas	jue 30/03/17	lun 03/04/17	36	Engineer
38			**12. DO PROTOTYPE 2**	**42,5 días**	**lun 03/04/17**	**mié 31/05/17**		
39			12.1 Do the program	50 horas	lun 03/04/17	mié 19/04/17	37	Engineer
40			12.2 Do sensors interact	35 horas	jue 20/04/17	mar 02/05/17	39	Engineer
41			12.3 Do tests in controllated scenarios	45 horas	mar 02/05/17	mié 17/05/17	40	Engineer
42			12.4 Do test in real scenario	40 horas	jue 18/05/17	mié 31/05/17	41	Engineer
43			13. ELABORATION DOCUMENT	10 horas	jue 01/06/17	lun 05/06/17	42	Engineer
44			**14. RECOPILATION DATA PROJECT**	**1,75 días**	**jue 01/06/17**	**vie 02/06/17**	**42**	**Engineer**
45			13.1 Recopilaion data project	5 horas	jue 01/06/17	vie 02/06/17	42	Engineer
46			13.2 File all information	2 horas	vie 02/06/17	vie 02/06/17	45	Engineer
47			FINAL	0 días	lun 05/06/17	lun 05/06/17		

Table 8.4 First project planning (part 2)

As we can see, till point 9 the programming of the project was the same, but once we pass this point we realized about things we did not take in account.

First was the selection of the device to do the recompilation data, by the beginning was the Raspberry Pi, but once we started to do the acquisition data we saw was not enough powered and does not comply with the specifications of the project. As the device to do the acquisition is the heart of the project, everything changed and a new search of information of sensors and data acquisition was needed.

By the end a new device was found, a DAQ of National Instruments which offered us all the project needs, so we started to work on it. As this device had his own software, we had to learn about it and do some programming exercises.

Moreover, we realized the distance sensors that were chosen were not the best ones for the monitoring of the test bench, so a new research of distance sensors was made.

The time of the delivery of the devices was other thing was thought that should be easy, but we saw was hard to find a provider with a short time of delivery, we saw the majority say they have at least 3 to 4 weeks of delivery, but by the end was even more for the distance sensors. This was not taken in account and was not good because lot of time could be lost.

The most important thing was the Load test itself. For the beginning of the project was programmed to be done on the third week of May. Kimua is a company who offers solutions in lifting maneuvers, so they design and build tools and those ones are which they test on the test bench. The first postponement was due the materials of the tool, the provider had 3 weeks of delay. Then the second date programmed was for the third week of June but this one was canceled too due the tool was not finished. A third date was programmed then and was for the second week of July. Their client was supposed to go the July 18 to do the load test, but they could not assist and nowadays is still on waiting list. It is programmed they will go to the Kimua installations the third week of September.

That does the implementation of the devices get on waiting list and on the company the preferences were others, so the third week of July they only did few tests with the equipment, not the load test because they did not have time enough for this.

All those things did the first programming of the project was far away from the reality and that are the reasons why do the delivery on June 8 was impossible and we did an extension of the project till the load test was done and the devices arrive.

For the economical way, with the raspberry device and with the first sensors chosen the total budget about 20.000€ but with all the changes done and with the extension of the project the total budget was 34.710,02 €, bit more of 14.500€. This increasing of the price is especially due the new DAQ, computer and devices which are bit expensive from the other ones and the hours more worked. Moreover, four measurement distance sensors were added to the test bench, to see if the frame has deformation.

9. Conclusions.

This Project at the beginning was very ambitious. The first proposal of the company was to monitor the tower masts lifting maneuvers wire-less but since the first day we saw was too much for a project from zero and to be a final project. Then the project was reappointed to other way, a previous step to achieve this on the future.

A monitoring of their test bench which is located on the Vasc Country was chosen to start the tests before achieving this. As I am mechanical, not electronic engineer for me the project was a real challenge, maybe one of the difficult ones I have done on my life.

From the beginning I had to search information about everything, we can say from zero because were things that I have never seen or used before. That means before start to search electronic devices I had to inform and study a bit about them. Let's not talk about the programming work. I had to do a big effort on programming devices and learn about things we did only few things the first year of the degree, but in this case more complex and difficult.

From the project we can observe the following points.

Strong points

The chosen devices are for sure the best ones for the project. A really background work was done. Moreover, the advices of the providers who work with this daily were useful to do the choice.

This project is focused in a field which is growing nowadays and there are companies who offer something similar but not a lot, it means if by the end it works correctly a new way of commercialization could be open (nowadays is not contemplated).

The useful life of the devices is extremely long, as they don't have a maintenance if the equipment is treated with care will last long time. Moreover, if some device fails or it broken lot of spare parts are available.

Weak points

As the program was not tested I cannot assure the total function of it, for sure there are some adjustments to do.

The designed pieces to do the implantation of the linear position transducer are still for build, the effectiveness of they are not tested yet. But for the design and the simplicity of them for sure will be the right ones.

Personally, I have to thank to the Kimua company for offering me the opportunity to do a real project, although by the end that not finish as I wish. I have learned lot of new things, not only academical ones, the treatment with providers, the meetings and how to procedure with them, I could see personally how you do your best to do a planification, and how this can be affected by other things you don't have the control, and this gave me other perspective in how to procedure with this kind of situations and honestly, I think is the finality of a real final project.

As I mentioned before the project did not finish as I wanted. The idea was to go to the Kimua installations to do the implantation of the devices and do a load test with a new tool they had to do, but due their timetables and preferences the dates were changed couple times arriving by the end to the cancelation of it.

I hope they can finish it soon and give me the final results, thing I am really looking for.

The future line of this project is to achieve the monitoring of the tower masts while they do the liftings. I really think this is possible following the lines of our project and the study done. The DAQ is the best device to achieve this, but for this case the same one that we used for this project is not valid, they must use the CompacRio device instead the USB DAQ. This one is bigger, stronger and more powerful device and offers the possibility of wire-less connections.

If they achieve to do this, for sure they will have a new device on the market which they will can offer to other companies and do business with it, which is the final objective of them.

10. References.

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[2] Theory of basics on hydraulic systems: http://www.hydraulicsonline.com/an-introduction-to-hydraulics

[3] Differences between analog and digital sensors. Basics on sensors: http://blog.robotiq.com/whats-the-difference-between-digital-and-analog-i/o

[4] Patent similar to the project we want to do with the name 'control method and controller for mechanohydraulic system', for more information visit: https://patents.google.com/patent/US8099196B2/en?q=sistema&q=hidraulico&q=medicion

[5] FAGIOLI COMPANY, a company who do similar things that Kimua Group does, for more information visit: http://www.fagioli.com/fagioliUk/monitoring.htm

[6] Raspberry Pi 3. Minicomputer used on the project, for more information visit: https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

[7] National Instruments is the biggest company in acquisition data, for more information visit: http://www.ni.com/es-es.html

[8] Catsensors is a company which is a supplier of different kind of sensors, for more information visit: http://www.catsensors.com/es

[9] Encosolution is a company which is a supplier of different kind of sensors, for more information visit: http://www.enco-solution.com/