Intelligent system for monitoring motor pumps in the water supply to optimize crop rotation

Sistema inteligente para el monitoreo de motobombas en el suministro de agua para optimizar rotación en cultivos

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Abstract

In the agricultural sector of the municipality of Guasave, diesel pumps are currently used to irrigate the various crops, this due to the lack of water that has occurred in recent years. To do this, these pumps are mostly manufactured with very rustic physical structures and only with analog markers that are not very precise. This situation keeps the equipment unprotected and only shows parameters analogically, this makes the process inefficient. With the present project, we designed, developed and simulated a prototype of a system that evaluates and monitors the physical parameters that influence the operation of different thermal machines used for pumping. To achieve the above mentioned, a series of sensors were installed, the signal is sent to Raspberry Pi 3, in which the data is processed, stored and shown to the user of the equipment through a graphic interface. A possible improvement of this system in the future would be to create a mobile application, which in real time, could alert the user of possible failures, decreasing the side effects on the environment, optimizing crop rotation for the continuous improvement of the competitiveness of the agro-industrial sector in northern Sinaloa.

Innovation, Technology, E-learning

Resumen

El sector agrícola del municipio de Guasave, actualmente se utiliza bombas a diésel para poder regar los diferentes cultivos, esto debido a la falta de agua que se ha presentado en los últimos años. Para hacer esto, se fabrican estas bombas en su mayoría con estructuras físicas muy rusticas y solo con marcadores analógicos que son poco precisos. Esta situación mantiene desprotegido al equipo y solo muestran parámetros analógicamente, esto hace ineficiente el proceso. Con el presente proyecto, se diseñó, desarrolló y simuló un prototipo de un sistema que evalúe y monitoreé los parámetros físicos que influyen en la operación de distintas máquinas térmicas usadas para bombeo. Para lograr lo antes mencionado se instalaron una serie de sensores, la señal es enviada hacia Raspberry Pi 3, en la cual son procesados los datos, almacenados y mostrados al usuario de los equipos a través de una interfaz Graphic. Una posible mejora de este sistema en un futuro sería crear una aplicación móvil, que en tiempo real, pudiera alertar al usuario de posibles fallas, disminuyendo los efectos colaterales en el medio ambiente, optimizando la rotación de cultivos para la mejora continua de la competitividad del sector agroindustrial en el norte de Sinaloa.

Innovación, Tecnología, E-learning

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Introduction

In the state of Sinaloa, specifically in the municipality of Guasave, it is common to use diesel pumps to irrigate the different crops that are planted. For this you have pumps, mostly with very rustic physical structures and only with analog markers that are not very precise.

Throughout history, this town has been characterized by promoting the development of agriculture since it is the main economic activity in the region, being known as the agricultural heart of Mexico, that is why over time it has had to look for alternative irrigation systems due to the effect of droughts that have occurred throughout the growing seasons.

There are different irrigation methods which can be used on flat or sloping lands; depending on the land, water availability and harvest; According to these characteristics, they are divided into 3 types of irrigation, as we can see in Figure 1.

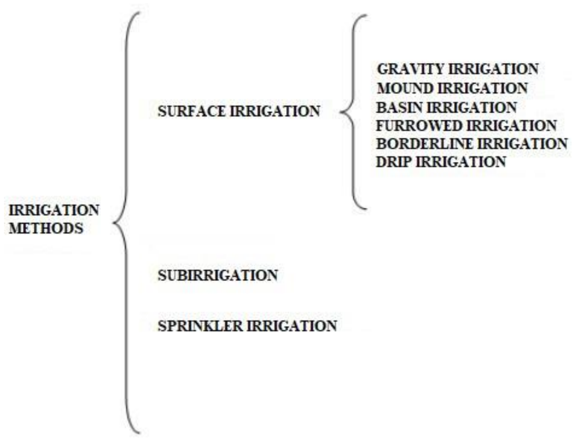

Figure 1 Irrigation methods.
Source: (Delgado, 2010)

Regardless of the irrigation method used, currently some pumps are used to do so, which make it easier to carry water from one place to another. For this, there is a great variety of pumps used to provide the water with the necessary energy to be propelled and reach its destination. Those most commonly used in agriculture are the so-called turbo machines, in which there is an increase in the speed of the water caused by the rotating movement of an element called an impeller or impeller, made up of blades.

Given these conditions and the increase in the use of pumps for the transfer of water, the need arises to create systems that help this activity to be carried out more efficiently, therefore some related research works are presented below. which this work is based on.

In (Escalas Rodríguez, 2014) an automatic irrigation system controlled with Raspberry Pi and Arduino installed by a gardening company is proposed. This system is called REGPI and works based on sensors connected to a microprocessor with an internet connection, this allows the system to be controlled remotely through a web browser, this can be seen in Figure 2.

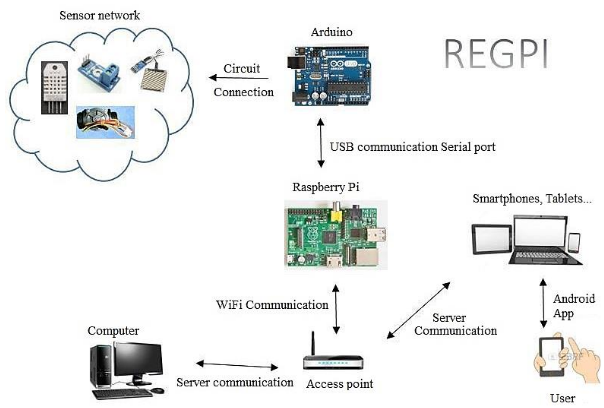

Figure 2 REGPI system operation diagram.
Source: (Escalas Rodríguez, 2014)

(Alamoto Barahona, 2016) present a prototype of a drip and sprinkler irrigation system which is automatic, all this through a remote control device, a web page that allows you to indicate the on and off times of the system, and which also allows storing system information in a database. In Figure 3 we can see the block diagram of this system.

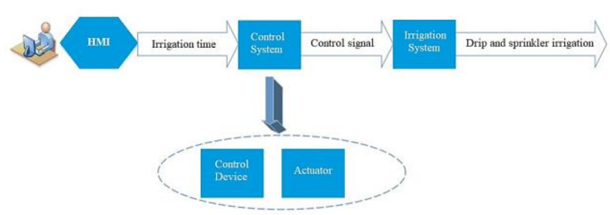

Figure 3 Block diagram of the automated irrigation system
Source: (Alamoto Barahona, 2016)

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In (Ruiz Molina, 2014) a thesis is presented with a topic related to data conditioning, acquisition and storage, taking into account the LabVIEW program and other programs related to signal processing, which makes this work contain valuable information for this project . In this thesis, microcontrollers with USB storage units and a network connection system called Ethernet are used for data collection, on the other hand, the analog signal of the translators of the system to be monitored is adapted to be able to process and save them. The general structure of the system can be seen in Figure 4.

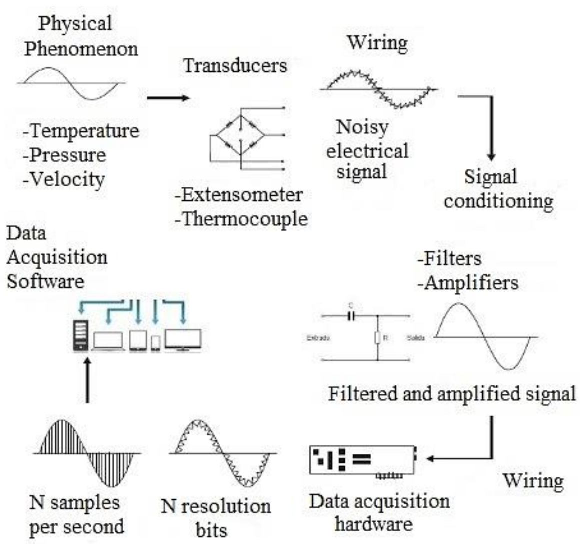

Figure 4 General structure of the system
Source: (Ruiz Molina, 2014)

In Anaya & Ojeda, 2020 they present a thesis that proposes a greenhouse prototype for the cultivation of edible plants, vegetables and fruits in closed environments, in a controlled and automated way. They do this through an Arduino electronic board, the most significant environmental variables that influence plant growth are controlled in an automated way, such as temperature, air humidity, soil humidity and lighting. Likewise, a mobile application was developed, which allows the monitoring and control of the crop or plant inside the greenhouse.

Bosh, 2013 elaborated a thesis that consists of developing an intelligent monitoring system for multilevel inverters, which detects semiconductor faults by only measuring the terminals (states and outputs) of the transistor modules.

Among the specific objectives are the following: To develop a methodology that identifies the instantaneous operating status of all semiconductor modules type H-bridge, three-phase bridge, and NPC bridge. Prepare a protocol that identifies or discards faults, based on the states observed from the outside, in the modules of different bridges. Implement an intelligent monitoring system that identifies or rules out failures in a three-phase bridge inverter, based on the observed states. Develop a graphical interface that displays information regarding the operation and status of the inverter.

Problem Statement

In the municipality of Guasave, agriculture has achieved significant progress over time, with producers using cutting-edge technology for various processes.

Such is the importance of the development that agriculture has at present, which represents 70% of the total area of the municipality, from which several aspects emerge, one is the fact of having 346,441 hectares destined to that economic activity, of which which 181,542 hectares are destined to irrigation. (Municipalities.mx, 2018).

One of the main problems for this activity in recent years and which will worsen in the future, is the lack of irrigation water. As mentioned in (FAO, 2003) to alleviate these problems “proposes a strategy to reinvent water management in the agricultural sector, based on the modernization of irrigation infrastructure and relevant institutions, the full participation of water users. water in the distribution of costs and benefits, and the drive for underinvestment in key sectors of the agricultural production chain”.

For this reason, different irrigation techniques have been used to make the most of this resource. One of these techniques is the use of irrigation pumps, which allow farmers to transport the vital resource to their crops in an easier way.

However, these pumps generally do not have automated systems, which allow monitoring and preventing failures during their operating time.

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Given these problems, this project aims to develop a system that allows the user to show accurate readings of the equipment operation, keeping an operation history and through a security module to protect the motor against common failures in the system. On the other hand, this system can be installed on computers that share its problems, even if they are used for different purposes.

The price of installing the equipment would be relatively low considering the benefits it will have for the equipment and therefore the owner and / or user of the same.

That is why this project proposes the realization of the design and simulation of a monitoring and protection system applied to diesel pumps, it is aimed at controlling the operation of an internal combustion engine coupled to a snail-type pump used for crop irrigation. agricultural. The system works by collecting the signals from different sensors installed in the pump and displaying them on the screen and deactivates the equipment if the values provided by the sensors are outside the operating range, protecting it against costly damage, controlling and monitoring the equipment variables can protect it. against failures and avoid downtime and more accurate readings.

The steps to follow to develop the project was to follow an investigation of the operating conditions of the pump, as well as its operating characteristics. On the other hand, a series of options was investigated to choose the most suitable software and hardware to carry out the project, evaluating different options and thus moving on to the design and simulation of the monitoring system, the design was carried out on the Raspberry Pi and the simulation on a Windows PC given its software compatibility. Finally, the system was applied to the equipment operating in the real field and evaluating its performance.

The development of the project led us to obtain a design and simulation of a prototype with a multiplatform application in the Python language that can be executed on Linux and Windows operating systems, in addition to obtaining simulated data and randomly generated by a microcontroller.

A prototype was used to simulate the switching on and off the pump by means of a relay having a response of the correct operation of the system in addition to the real field tests carried out.

State of the art

Monitoring systems are indispensable in industries, where they can be implemented to optimize available resources. For example, the processes necessary to give proper use to water in hydraulic supply systems, consumption centers or discharges, among others, where it is necessary to measure and / or keep constant some quantities, such as the pressure of a line, the level of a cistern or the instantaneous expense in a pumping station, among other variables.

Monitoring generally means being aware of the state of a system, to observe a situation of changes that may occur over time, that is, there is no manual or automated question about the control of variables, it is only the visualization of the changes in instrumentation according to system conditions; This monitoring can be carried out with the personnel and their tools in hand, or with the automatic intervention of the instrumentation equipment integrated with transmission devices through local or remote networks, which send information to a monitor or to an administration panel of the variables.

Automation is the application of automatic machines or procedures in the performance of a process or in industry. The goal of automation is to generate as much product as possible in the shortest time possible. Automation can be applied in many industries including textiles, electronics, food, automotive and agriculture.

The latter as the most important for our region, specifically in irrigation, which constitutes various procedures that allow the efficient distribution of water on the soil surface, where the implementation of new technologies will allow us the opportunity to attend a time where automation will be massive. Planting, irrigation, maintenance, surveillance, control and even harvesting will be automated. (Agricultural ERP, 2016)

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Regardless of the industry where it is applied, an automated system is made up of different components, among which stand out, the instrumental part, the sensors, the control software and the communication systems.

Instrumentation is a set of instruments necessary to carry out an activity or reach a solution, this allows us to measure variables of matter in its different states, gases, solids and liquids, hydraulics and pneumatics provide us with the necessary force to move motors or servomotors, which are in charge of the dynamics in automation, as well as to move a pump, press or move an object (Torres Montero, 2015). Within the instrumentation we can find different components such as:

A Water Pump or Motor Pump is a piece of equipment that has the same operation as any hydraulic pump. They are teams that transform Mechanical Energy into Kinetic Energy. That is, in the end it is necessary to generate a movement of the liquids that are to be used. When the pump receives that energy with a coupled motor, be it Gasoline or Diesel, the Water Pump is called a Motor Pump, if the energy is by electric current it is called an Electric Pump. The power they develop and the characteristics of their cooling systems allow long-term use. Some advantages and disadvantages of these are (Ventageneradores, 2016):

Advantage:

- It does not require contracts or supply companies.

- It does not require paying for the installed power that you have.

- There are no surcharges.

Disadvantages:

- It is not a system with full autonomy, due to the fuel used.

- They are louder systems.

- They have a relatively higher initial and maintenance cost.

- In most cases they do not allow automation.

A sensor is a device that measures, automatically or directly, a variable and provides an output signal, which is a function of the variable to be measured. There is a great variety of sensors, depending on the magnitude to be measured and the characteristics that they want to have, as well as their application (Corona, Abarca, & Mares, 2014). These tell us what is happening in the processes, where you are at a certain time and send a signal that allows you to continue with the next process. Some examples of sensors can be:

Pressure sensors or pressure transducers are very common in any industrial process or test system. Their objective is to transform a physical quantity into an electrical one, in this case they transform a force per unit area into a voltage equivalent to that exerted pressure (Araya, 2009).

Temperature sensors are devices that transform changes in temperature into changes in electrical signals that are processed by electrical or electronic equipment (Corona, Abarca, & Mares, 2014).

RPM sensors base their operation on the electromagnetic phenomenon, that is, the relationship between magnetism and electricity. When a coil is subjected to the variation of a magnetic field, an alternating electric current is produced in it, produced by the effect of magnetic induction. It is responsible for informing the momentary revolutions of the engine. It is composed of a coil wound on a magnetized core (Guarella, Heredia, Rodríguez, & Bagatto, 2011).

On the other hand, there are the control and communication systems, which are composed of both software and hardware, these link all the parts and the logic controllers, they are in charge of controlling that everything has a sequence, making decisions according to a established schedule. Within this category we find components such as:

Arduino is an open electronics platform for prototyping based on flexible and easy-to-use hardware and software. It can take information from the environment through its input pins from a whole network of sensors. In this case, Arduino will be controlled by the Raspberry Pi (Escalas Rodríguez, 2014).

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Raspberry Pi is a low-cost computer and consists of a motherboard on which a processor, a graphics chip and RAM are mounted. As for the operating system, several can be installed, most of them based on the Linux kernel. (Rodríguez Scales, 2014)

To do all the software part, there will be two programming tools such as the Arduino IDE and Python. IDE stands for "Integrated Development Environment". This IDE was installed on our computer, and it is a very simple environment to use and in it the program for the Arduino component was written. (Martínez, 2015)

Python is a powerful and easy-to-learn programming language. It features efficient, high-level data structures and a simple but effective approach to object-oriented programming. (Santana Roldan, 2013)

Methodology

The methodology to be followed will be based on the specific objectives of the project, and will be shown in (Escalas Rodríguez, 2014), starting from a field investigation, where the phenomenon was studied directly, and from this study, defining the requirements that the proposed monitoring system would have.

In Figure 5 you can see a block diagram of the activities carried out.

Figure 5 Block diagram of the project.
Source: Own elaboration, (2019)

Field study

For the field study, a survey was conducted of 100 people related to agricultural activity such as farmers, SAGARPA staff, as well as experts from the agricultural area, this in order to know what is the utility that is given to the equipment pumping and how careful they are with such equipment. In addition, it also served to know what are the costs of carrying out repairs on the pumping equipment used in the region, as well as the costs of a new equipment.

In the same way, the physical characteristics of the motor pumps used for irrigation in the region were studied, of which it was mainly identified which variables were of interest in their monitoring both for the equipment itself and for the user.

Likewise, it was studied how the different parameters are currently measured, the types of sensors used by the motor pumps, if they used them, and how they could be measured for use in this project.

For this, visits were made to different producers that had irrigation motor pumps, as well as the facilities of the Association of Agricultural Producers Users Petatlán Module II-1 A.C., and thereby collect the necessary information.

Monitoring system design

Once the field study was carried out, the system requirements were identified in terms of hardware and software aspects.

At this point, an exhaustive search was carried out for possible sensors that were adapted to the project, mainly according to their physical characteristics, operation and cost. Based on these characteristics, the best options were chosen.

The temperature sensor chosen was a type k thermocouple, this given its characteristics made it ideal for our purpose. The 1G / 4 pressure sensor with a 174 Psi range given its cost and durability.

The same was done for the software, the possible programming languages that fit with the different hardware parts were studied, without the need to raise the cost of the prototype, which should preferably be free software languages.

Several programming languages and tools were tested, leaving in the end the options of MyOpenLab due to its versatility in this type of application, as well as the Python programming language, which due to the characteristics of the native operating system of the Raspberry Pi, made it ideal for this Proyect.

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Based on the analysis that was carried out, a design of the monitoring system was carried out, in this design the two main aspects in which it is proposed to divide the project were considered, such as the hardware part and the software part.

This design should allow the sensors to send signals to the Arduino and Raspberry Pi modules, so that they could be processed and display the different measurement parameters on a screen for the operator and at the same time a history of the parameters obtained during operation was saved. equipment, and a system to protect the equipment against operating errors had to be programmed.

In Figure 6 you can see the design proposed for the proper functioning of the monitoring system.

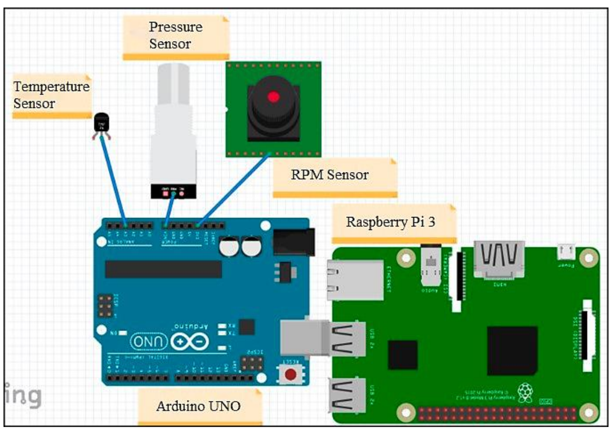

Figure 6 Physical diagram of the prototype
Source: Own elaboration, (2019)

In addition, as the system had to be installed in the pumping equipment, the design of a cabinet was also made, which contained the display screen and the Arduino and Raspberry components inside, this design is shown in Figure 7.

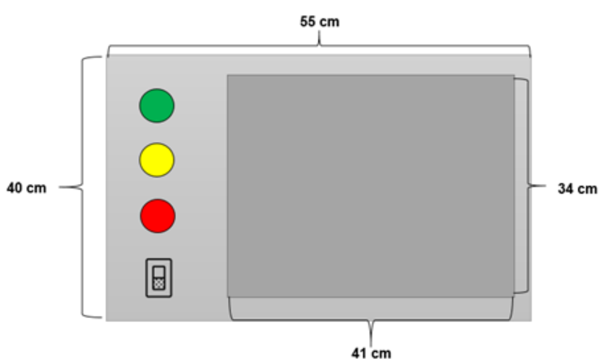

Figure 7 Designed Cabinet Dimensions.
Source: Own elaboration, (2019)

Prototype development

Once the software and hardware requirements had been established, in addition to verifying the shape of the monitoring system cabinet, the development of the prototype as such was carried out.

The first of the activities carried out was to test the sensors, here the necessary connections were made with the Arduino module, according to the design, this was used as a data acquisition card. It performed the function of an analog to digital signal converter, in addition to serving as a means of protection between the devices and the Raspberry Pi, in the event of an electrical failure, thereby ensuring that the data stored by the system would be protected. The Arduino module was used since the Raspberry Pi does not have analog inputs, and as mentioned above the sensors provide us with analog signals.

Once the signals were converted to digital in the Arduino device, it sent the measurements from the sensors to the Raspberry Pi, through serial communication, through a USB connection.

Received the data in the Raspberry these were processed and displayed on the screen. All this through an application developed in Python. It was more viable since, in addition to being free software, the applications created with it are multiplatform, that is, they can be run on almost any computer and on any operating system without any problem.

All the data received is stored in a text file, this for later consultation, with which the behavior of the equipment during its operation could be studied, and in case of failures, it can be possible to locate when they were and what failed.

In addition, the monitoring system has a protection system, where in case of detecting measurement parameters of the sensor signals, it automatically stops the equipment, this in order to prevent failures and breakdowns of the different components of the equipment. pumping. Some of the failures can be high or low oil pressure, high temperature, dry work, that is, the equipment is not pumping water or any liquid, among others.

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Simulation

The Python application is cross-platform, this means that we can run it on both Windows and Linux, that is why the simulation tests were done on a Windows computer, but with the same application that was run on the Raspberry Pi.

First, Arduino was programmed with a special code for random data using the “random” instruction, this is used for random numbers within a certain range, which can be configured in the code. For this we established the ranges of the variables according to the readings in which this type of equipment can be handled.

In addition, the operation of the Arduino was simulated by means of a simulation software called MyOpenLab, this software is multiplatform, for this reason it can be run on the Raspberry Pi and on a computer, for this we use Arduino as a data acquisition card, programming it from the software to enable or disable outputs on the Arduino.

The programming is done through a library called "Firmata", which is loaded into Arduino and links it to the software, then the inputs and outputs of the Arduino are activated from the software.

Then, the programming of the inputs from which the signal was received is done and all kinds of operations are done to manipulate the output that was activated from the Arduino. In Figure 8 we can see the programming carried out and the final interface.

During these simulations, an LED lamp was turned on and off, which served as the system pump.

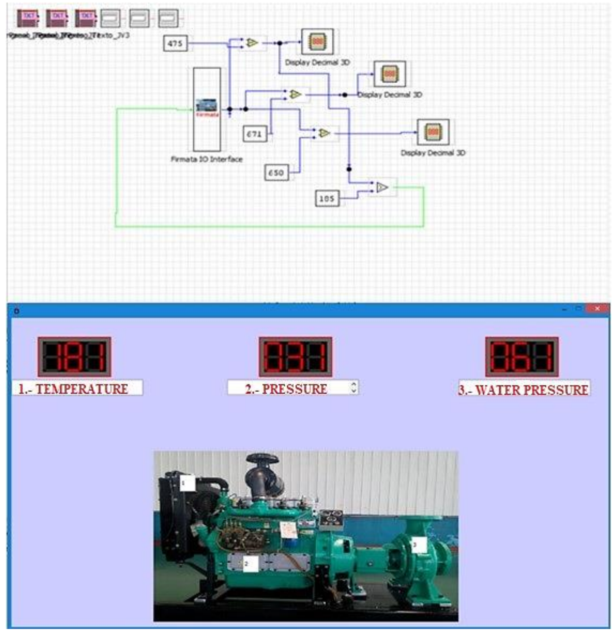

Figure 8 Interface programming in MyOpenLab.
Source: Own elaboration, (2019)

Field tests

In this part of the methodology, the monitoring system was applied in a real environment, the pressure and temperature sensors were installed in a pumping equipment. This equipment was loaned by the Petatlán Guasave irrigation module, and was carried out on the banks of the Sinaloa River. The pump used for the field tests can be seen in Figure 9.

Figure 9 Pumping equipment with the prototype installed.
Source: Own elaboration, (2019)

The water pressure sensor could not be installed as the owner did not have permission to modify the physical structure of the centrifugal pump coupled to the motor.

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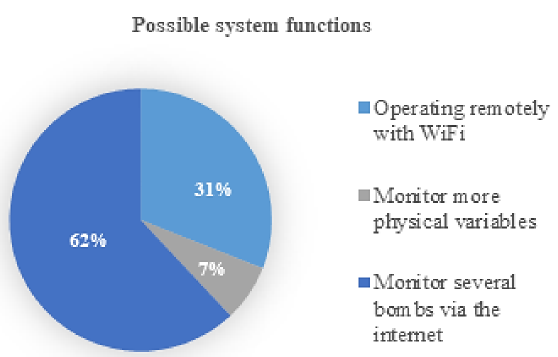
Finally, the monitoring project was applied to another type of diesel engine, such as the Yanmar Thermo King 2.35 engine, which is shown in Figure 10.

Figure 10 Yanmar engine used for testing.
Source: Own elaboration, (2019)

Results

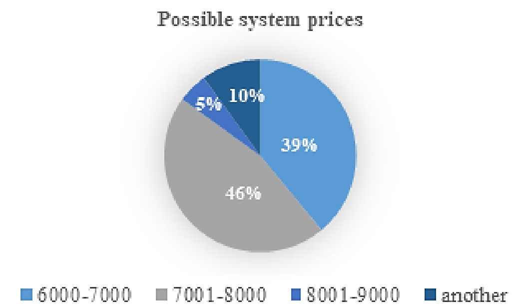
According to the activities carried out during the project period, different results could be obtained:

First, qualitative information was obtained from the surveys of users and experienced personnel in the area. In Graph 1, we can see that, as a result of one of the questions in the survey, people gave their opinions about possible new functionalities that this project could have, to which 62% believed that the best option would be to link several pumps through the use of the internet.



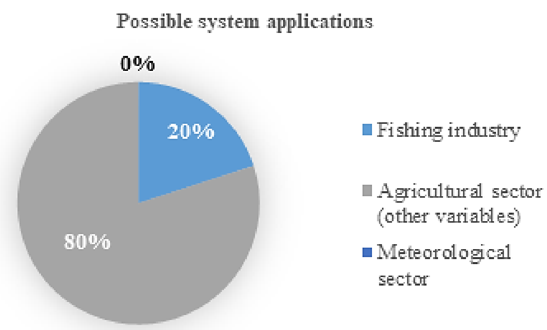
Graphic 1 Results of possible system functions.
Source: Own elaboration with information collected in surveys carried out, 2019)

In the same way, respondents were asked about the prices they would be willing to pay for the system, to which 56% responded that the price to pay could range between $ 7,000 and $ 8,000 pesos, as can be seen in the Graphic 2.



Graphic 2 Results of possible system prices.
Source: Own elaboration with information collected in surveys carried out, (2019)

In addition, it was also asked about other applications that could be given to the system, this in order to expand the target market, to which 80% of the respondents answered that another application could be the aquaculture sector, as observed in the Graphic 3.



Graphic 3 Possible system applications.
Source: Own elaboration with information collected in surveys carried out (2019)

Tests were also carried out on the hardware components, mainly on the sensors, for which it was possible to corroborate that they gave real measurements, for which, the measurements obtained in the system were compared with commercial meters of the different parameters, showing very good results. similar, we can see this in Figure 11, where pressure and temperature readings obtained in the system are shown, and those obtained in a pressure gauge and a digital infrared thermometer, where the pressure reading approaches 50 psi and the temperature at 25 ºC.

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June 2020 Vol.4 No.6 14-25

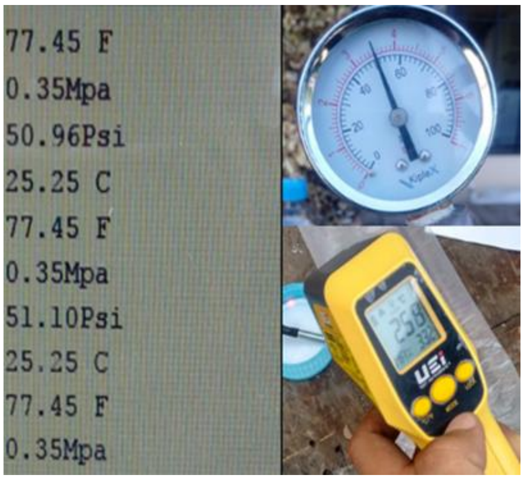

Figure 11 Comparison of measurements between the system and commercial meters.
Source: Own elaboration with tests carried out (2019)

Once the hardware components were tested, tests were carried out to be able to choose the best Graphic interface for the system, this through different programming languages, in Figure 12, we can see different designs made both in MyOpenLab, and in Python.

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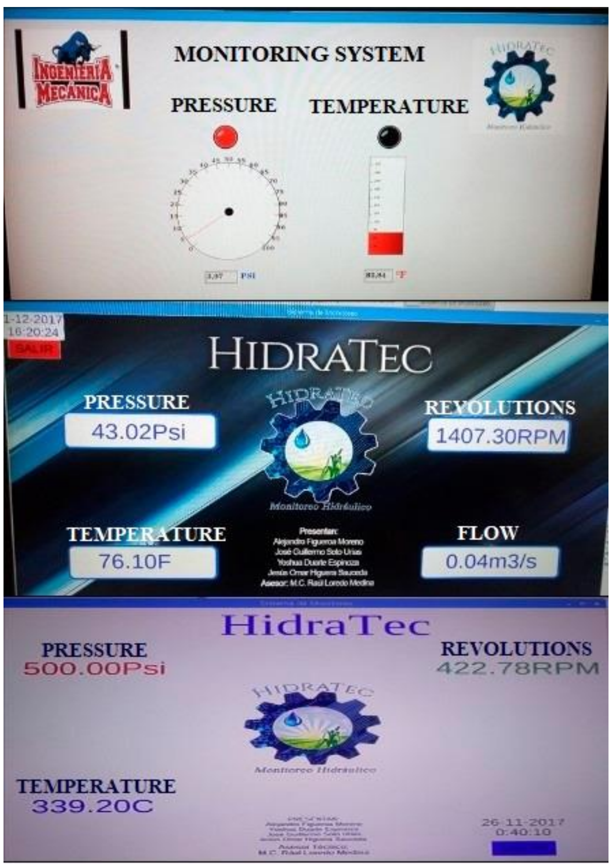

Figure 12 Graphic interface tests of the system.
Source: Own elaboration with tests carried out (2019)

In Figure 13 the final prototype of the system is shown, you can see the cabinet installed in the motor pump where the field tests were carried out, these were carried out in the facilities of the Guasave-Petatlán II-1 Irrigation Module, on the banks of the River Petatlán. In these tests, the system was left running for a certain time to observe how the measurements varied..

Figure 13 Monitoring system in field tests
Source: Own elaboration with tests carried out (2019)

Finally, it should be mentioned that in the field tests it was not possible to test the protection system, since if the motor pump failed, it put the equipment at risk, and for safety reasons, the company asked us not to do it. . However, a simulation of the protection system was carried out, for this, threshold data was established for each monitored parameter, which are, temperature greater than 185 ° F, oil pressure less than 55 PSI and water pressure less than 25 PSI Once these thresholds were passed, the application through Arduino ordered the system to turn off, which in this case was simulated by a lamp which was connected to a relay.

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Conclusions

Climate changes currently have meant that food production processes, specifically in agriculture, are also modified. With these changes, it is increasingly common to see the use of new tools, which help to automate these processes, with the help of new technologies.

For this reason, in this work the design and development of a monitoring system was carried out, which automatically allows obtaining measurements in real time of different parameters of interest in the operation of pumping equipment, in this case diesel motor pumps. , and according to these measurements to be able to detect possible failures or malfunctions and make the equipment stop automatically, which can prevent expenses for repairs or purchases of new equipment, which would involve savings in both time and money for users of this type of equipment.

According to the results obtained both in the simulations and in the field tests, we can conclude that the developed prototype is functional. In addition, this same prototype can be used in applications where equipment with similar operations is handled, and parameters can be added, depending on the purpose of the same.

As work in the future, it is proposed to extend the time to carry out field tests, and to try to find moments in which equipment failures occur, to verify if the monitoring system is capable of detecting it, since, for reasons of Logically, the equipment used for these tests was impossible to make them fail, since they belonged to a company external to us. Also, it is proposed to make a mobile application, which is connected to the monitoring system, with which messages can be sent to the operator and / or user of the equipment, where they can observe or monitor the equipment, in any place where be found.

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