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DEVELOPMENT OF AN ACQUISITION SYSTEM OF MATERIAL AIR FLOW TO GENERATOR SET USING ARDUINO PLATFORM

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Abstract. *This work aims to develop a reliable air mass flow acquisition system for generator sets using a low cost and easy to acquire platform. To achieve this purpose, the MAF type sensor of the supplier BOCH, model HFM 5 was used as main components; the test board of the manufacturer ROBO CORE, model Protoboard 840; and the board of the manufacturer Arduino, model UNO R3, as the main part within the system and responsible for connecting the sensors and actuators to the data acquisition system that will be executed in a computer. The software was developed in JAVA, which makes it cross-platform, through the NetBeans 8.0 development environment and using a mysql database 5.6.17. It is concluded that it is possible to create a reliable, low cost and easy acquisition system for mass flow of air and volumetric efficiency, for other quantities of a generating set and for other types of system, contributing to greater progress and equality within science.*

Keywords: Diesel engines, Air mass flow, Sensors, MAF.

1. INTRODUCTION

Data acquisition systems are, according to Emilio (2013), elements in scientific instrumentation and encompass sets of signal collection processes that measure real world physical conditions and convert the collected signals first into electrical signals and then into digital numerical values that can be stored by a computer for further analysis and treatment.

These systems are of great importance for research in the of thermal sciences field, since they are responsible for collecting and processing numerous quantities of one, for example, generator set, such as fuel flow, mass flow rate, temperature and rotation (Milhor, 2002).

The volumetric flow rate of air is a quantity used as the basis for some of the main measurements within a generator set, since it is one of the factors to calculate for the amount of oxygen entering the system and for its volumetric efficiency (Heywood, 2018).

In the academic area, there are major obstacles in relation to the purchase of acquisition systems, mainly due to their high prices. In the case of a system for acquiring air mass flow, monetary values, mainly through the supervisory system, make projects more expensive, making research in the area excluding and unequal.

In this sense, the objective of this work is to develop a generator set air flow acquisition system using a low cost and easy acquisition platform, for this, the Arduino platform was selected.

2. REFERENCIAL

2.1. Acquisition Systems

Acquiring data can simply be defined as measuring real world information. Most real-world events and their measurement are analog in nature. That is, the measurement can lead to a range of continuous values. These signals are then processed and transformed into data that will be stored in nonvolatile memories for later consultation. Figure 1 shows a simple scheme that exemplifies the process described above.

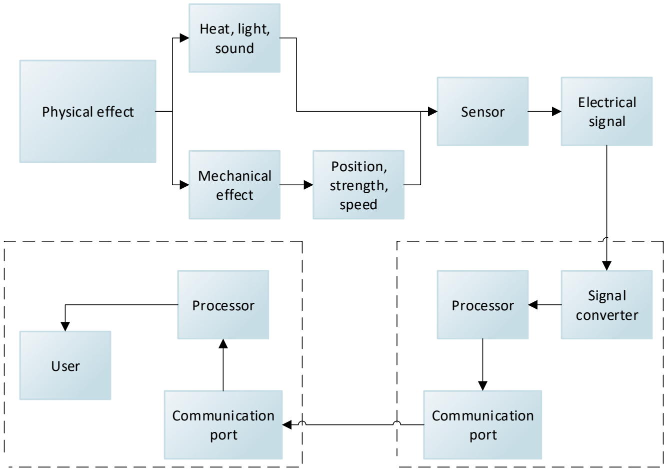

Figure 1. Acquisition System Example

Sensors and transducers sense it and produce electrical signals that acquisition systems measure (eg: thermocouples, temperature-dependent resistors (TDR's), thermistors, and sensors in integrated circuits convert the temperature to an analog signal that can be measured by an analog digital converter). We also have strain gauges, flow transducers, pressure transducers, which measure force, flow variation, and pressure, respectively. In each case, the electrical signals produced are proportional to the physical parameters under monitoring.

The mass of air that flows through a cross section per unit of time is called mass air flow. Flowmeters work to calculate the mass of the particular gas that passes through a cross section. The acquisition is made by MAF ipo sensors, the signal generated by these sensors is then counted during a known interval of time - pulse frequency - by the controller that performs a specific processing according to the specificities of each meter. in order to determine the mass flow of that short time. These pulses are still totaled to know the total mass of gas that passed through that section.

2.2. Arduino

Recently, according to Silva and Choque (2016), several projects have been created that allow and facilitate access to microcontroller programming to a wide audience, among them the Arduino Project (Massimo Banzi, 2011), Raspberry Pi (Upton and Halfacree, 2012), Edison (Stephanie Moyerman, 2015), Beagleboard (Derek Molloy, 2014).

In practice, Arduino is a small computer that can be programmed to process inputs and outputs between the device and the external components connected to it. This is physical computing, that is, a simple electronic prototyping platform able to feel the world around it, receiving inputs from a wide range of sensors, and acting on this same environment through actuators (Mcroberts, 2011).

Arduino makes electronic prototyping extremely easy and it favors not only beginners, but also more experienced professionals who can get their projects done faster. Another point that contributes to the use and choice of Arduino as a development platform is the concept of free hardware, to which it was developed. Allowing its use and distribution at no additional cost to the project.

However, Arduino does not yet offer the robustness that other programmable logic controllers have. PLCs are more reliable, have several industry certifications and many safety features. That is, these controllers are best suited for industrial applications.

3. MATERIALS AND METHODS

Through a graphical systematization, Figure 2 presents the methodology proposed in this research. The same was divided into two sections, the first fraction has the purpose of developing the acquisition system and the second part aims to carry out experimental tests using the system developed, and compares it to previously known and reliable bibliography. The detailed steps are described below.

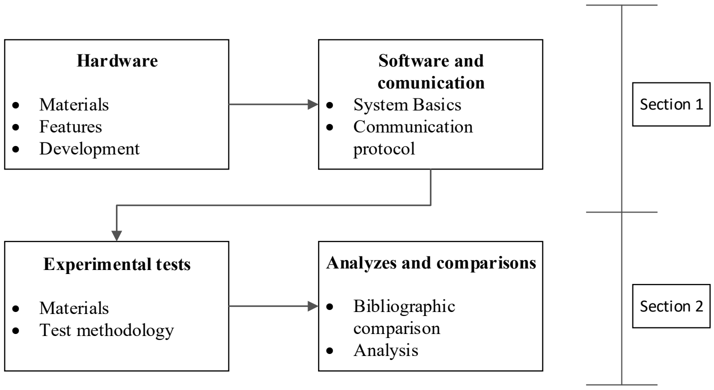

Figure 2. Systematization of the research methodology

3.1. System hardware

For the development of the system, the main components were the MAF type air flow sensor from the supplier BOCH, model HFM 5 (illustrated by Figure 3); the test plate from manufacturer ROBO CORE, model Protoboard 840; and the Arduino board, model UNO R3, as the main part inside the system and responsible for connecting the sensors and actuators to the data acquisition system that will be executed in a computer. Following are the MAF sensor specifications and operating principle.

- **Airflow sensor for intake air**

The Intake Air Flow Sensor (MAF Sensor) directly reports the allowable air mass by providing a voltage signal whose value depends on the air mass passing through it. The MAF sensor is installed in the airstream between the filter and the turbocharger and consists of a venturi with two platinum wires: one hot and one compensating wire, which measures the admitted air temperature. The venturi is suspended within the main duct of the sensor. An electronic circuitry incorporated in the sensor keeps the wire hot at a constant temperature of 100 ° C above the allowable air temperature. Air passing through the sensor causes the hot wire to cool. The electronic circuit compensates for this temperature drop by increasing the current flowing through the hot wire in order to maintain the 100 ° C differential.

Figure 3. Sensor BOSCH HFM 5

The MAF sensor manual defines a table with characteristic mass flow data as a function of the analog voltage read through the output terminal. The data reproduced by the manual are represented in Table 1.

Table 1. Mass flow x voltage

Mass Flow (kg/h)	Voltage (volts)
8	1,4837
10	1,5819
15	1,7898
30	2,2739
60	2,8868
120	3,6255
250	4,4727
370	4,940

3.2. Software and communication

The supervision system was developed in JAVA, which makes it multiplatform through the NetBeans 8.0 development environment and using a mysql 5.6.17 database. It has no installation procedure and its execution is performed through the NetBeans IDE working in the same way as the data acquisition system model presented in section 2.1 and exemplified by Figure 1.

3.3. Experimental tests, analyzes and comparisons

To verify the performance of the acquisition system and, at the same time, to validate it, a circuit was built to measure the volumetric air flow at room temperature, comparing the data collected to the high reliability bibliography. Therefore, consider Figure 5 as the experimental model used in the tests.

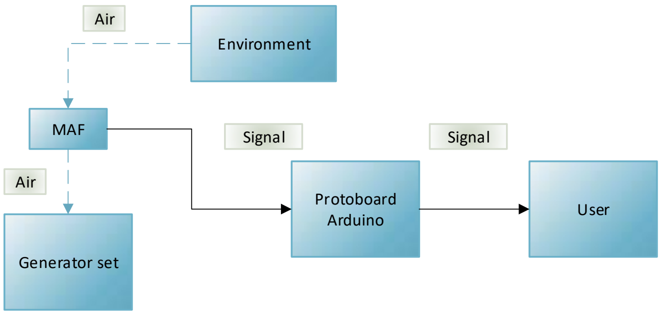

Figure 4. Graphic layout of the tests.

The system has been tested for multiple loads, with the interval between every 10-minute change to achieve stability. Figure 5 follows with the graphical representation of the tests, as well as the value of each load added to the generator set.

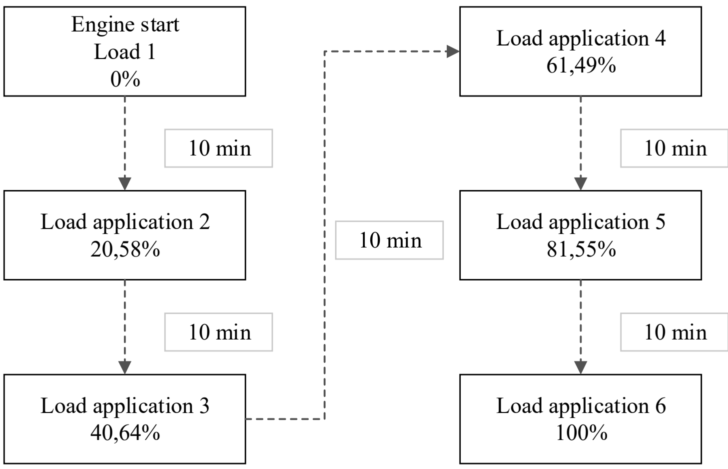

Figure 5. Graphical representation of proposed tests

In addition to the equipment already specified in section 2.2, the generator set of the brand Branco model BD-6500 CF3E was used, whose specifications follow the table below.

Table 2. Generator set specification.

Specification	**Data**
Generator set model	BD-6500
Engine	Horizontal, single cylinder
Cycle	Diesel - 4 stroke

Starter	Electric
Type of fuel	Diesel
Combustion system	Direct injection
Work Speed (rpm)	3600
Diameter (mm)	86
Stroke (mm)	70
Cylinder (cm³)	406
Compression ratio	19:1
Max Power (kVA)	5,5
Continuous Power (kVA)	5
Consumption (l / h)	2,15

4. RESULTS

4.1. Adjustment

Through the presented data we can define the graph of the tension as a function of the air mass flow as shown in Figure 4, a trend line with characteristic curve display was added which is presented by the equation described in the graph that will be inserted in the system code. data acquisition mode to read the analog channel that will be connected to the MAF sensor output.

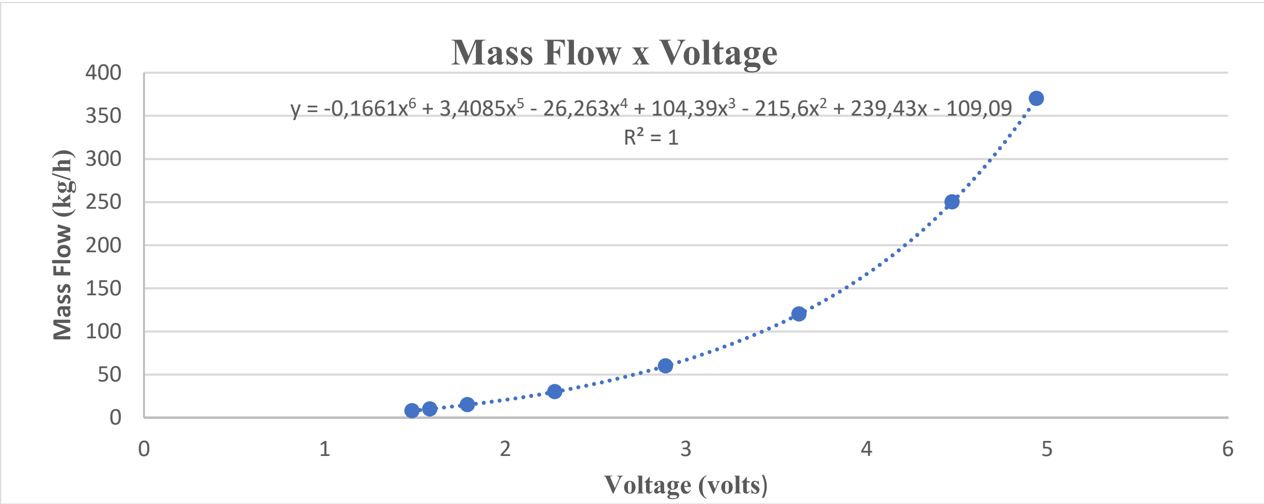

Figure 6. Voltage variation trend.

With the Adjustment made through the equation described in the graph, it was possible to generate the relative error of the adjustment represented by Table 3, where it is verified that the largest relative error was 0.81%.

Table 3. Relative error adjusted

Voltage (volts)	Mass Flow (kg/h)	Adjustment (kg/h)	Error [%]
1,4837	8	7,96	0,53
1,5819	10	10,08	0,81
1,7898	15	14,94	0,38
2,2739	30	30,03	0,10
2,8868	60	60,01	0,02
3,6255	120	120,04	0,03
4,4727	250	250,03	0,01

4,940	370	369,99	0,00

4.2. Test

For a better representation of the results obtained, the engine volumetric efficiency calculated by Eq.1 was determined using the actual mass air intake measured at the engine inlet, with the theoretical amount of air that could be allowed disregarding the restrictions and the effects. of air flow friction in contact with the walls of the intake manifold.

$$n_v = \frac{\dot{m}_{areal}}{\dot{m}_{ateo}} \quad (1)$$

Where the theoretical air mass consumption $\dot{m}_{ateo}$ is given by Eq. 2. ρ_{ar} represents the specific mass of air at local ambient temperature and pressure conditions, N represents the motor shaft speed per minute and n_r the number of turns to perform 01 (one) cycle.

$$\dot{m}_{ateo} = \frac{V_d * \rho_{ar} * N}{n_r} \quad (2)$$

Substituting in Eq. 1 the theoretical mass flow of air for Eq. 8 we have:

$$n_v = \frac{\dot{m}_{areal} * n_r}{V_d * \rho_{ar} * N} \quad (3)$$

For determination of volumetric efficiency, the specific mass of air was considered to be 1.2 kg / m³, the displaced volume (displacement) was obtained from the manufacturer's data and the rotation was determined using the rotation sensor.

By determining the specific mass of air at ambient pressure and temperature conditions and having the manufacturer's data, the theoretical mass air flow was determined with Eq. 2. The MAF sensor together with a type k thermocouple were installed between the filter and the engine intake pipe. Sensor power was supplied through a voltage source, and the sensor signal was interconnected at one of the analog inputs available on the acquisition board. The engine was started and real-time mass airflow measurements were made. The values obtained through the test allowed to calculate the volumetric efficiency of the engine together with the previously calculated theoretical air mass flow value.

The values for the volumetric efficiencies as a function of the loads applied to the generator set can be seen through the graph indicated in Figure 7. With the increase of the applied loads there is a larger fuel injection in the engine causing increased heat losses. As the genset installation environment is closed, the ambient temperature increases accordingly, the intake air temperature also increases, causing a reduction in specific air mass and volumetric efficiency.

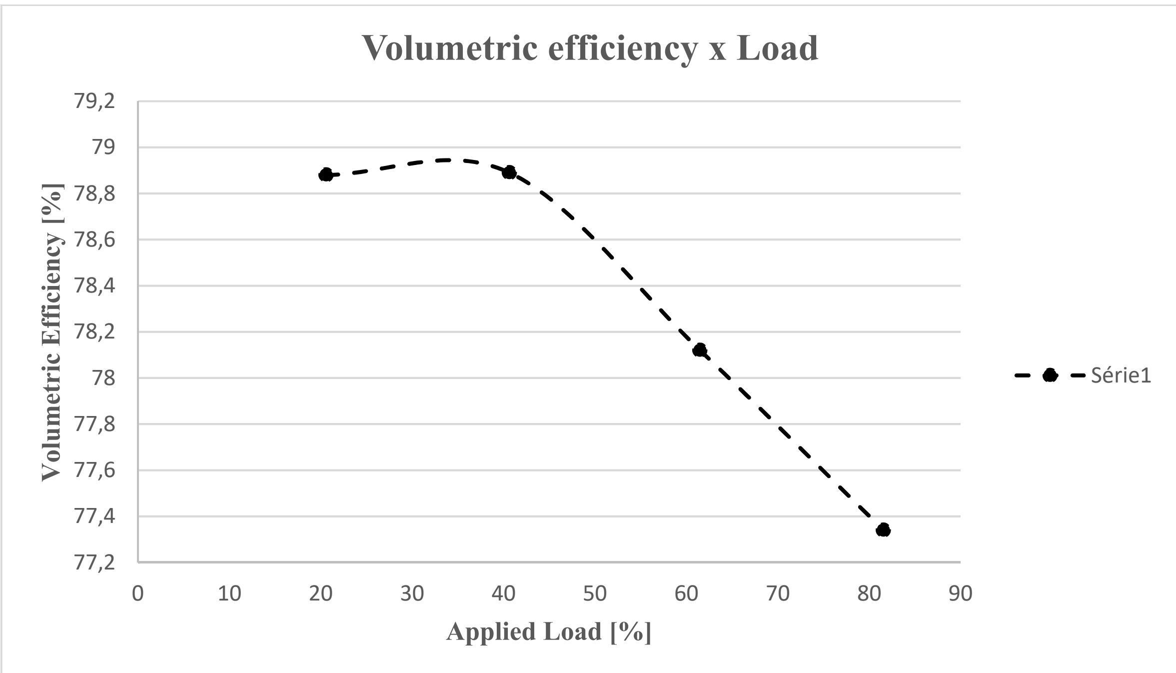

Figure 7. Volumetric Efficiency x Load

4.3. System Costs

One of the main justifications for the execution of this work was the low-cost proposal. In this sense, Table 4 presents the total cost of this project, reaching a total value of U$$ 59.50, compared to the current market price of Contemp A202 data buyer, U$$ 501.50, showing that the proposed system has a highly competitive value. It is noteworthy that the value of the BOSCH HFM 5 sensor has not been added as it is a necessary factor for both systems. Figure 8 shows the final design of the system..

Table 4 -System costs

Costs			
Component	Amount	Unit price (U$$)	Total price (U$$)
Arduino Mega Development Board 2560	1	15,00	15,00
Phenolite Plate	1	3,00	3,00
Cooler	1	2,00	2,00
Two-pin connection terminals	5	1,00	5
Capacitor	2	0,50	1
Resistor	1	0,50	0,5
Identification sticker (Optional)	1	3,00	3
Suitcase (Optional)	1	30,00	30
Total			59,50

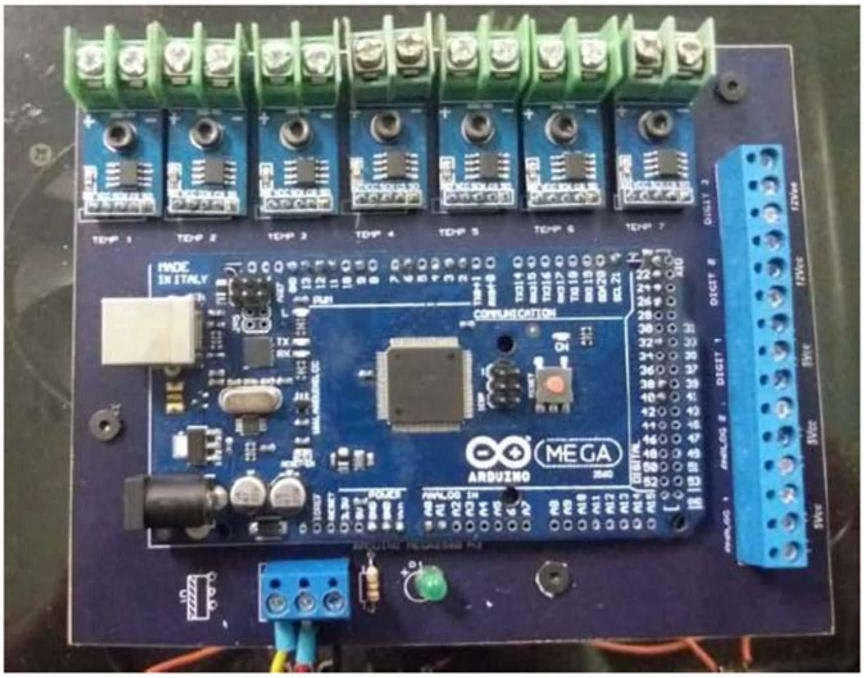

Figure 8 - Fixed system

5. CONCLUSION

From the data presented, it can be concluded that it is possible to create a reliable, low cost and easy acquisition system for mass air flow to determine the volumetric efficiency of an engine, for other quantities of a generator set, and other types of system, contributing to greater advancement and equality within science.

6. REFERENCES

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