

SCADA System for Supervision of Diesel Consumption and Energy Efficiency for Electric Generators

A. Jhonnathan González, Julián R. Camargo L and César A. Perdomo Ch*

Engineering Faculty, Universidad Distrital Francisco José de Caldas, Bogotá D.C., Colombia
jgonzalez@correo.udistrital.edu.co, jcamargo@udistrital.edu.co, cperdomo@udistrital.edu.co

Abstract

Objectives: This paper describes the process of designing a SCADA platform developed on a graphic programming environment using the Labview software tool. **Methods/Analysis:** Its purpose is aimed at monitoring the fuel consumption of diesel power plants and their electrical generation, making it possible through the interface and graphic indicators, to show the levels of level in the fuel tanks, the consumption of diesel in real time and electrical generation among others, in order to determine if a generator is behaving efficiently according to the indices determined by the manufacturer. **Findings:** If the operating criteria are not maintained, it would mean that fuel waste is being produced with the economic and environmental implications that it also implies that electromechanical corrections must be made in order for there to be efficient electrical generation. **Improvements:** You can use a web portal where you can monitor the system, adding a notification mode.

Keywords: Electric generator, diesel, Labview, SCADA, instrumentation for level, electric power

1. Introduction

Digital systems due to their characteristics of stability and reduced cost have been introduced in different fields including communications systems, within this aspect are the digital processing systems this is because it is easier to manipulate digital type signals than analog type.

The appropriate use of energy resources is a priority in all industrial fields, even more for companies that use fossil fuels such as oil, coal and gas and their derivatives such as gasoline, ethanol or diesel and the latter are used to power mechanical systems such as engines for electric generation or movement generation, it is well known the rise of new energy systems that protect the environment such as wind systems, solar energy systems, hydrogen systems among others, but still its implementation, cost and efficiency for Many industrial environments are not enough to displace conventional fuels, as in the case of

heavy machinery, electric generators, aviation sector, etc., where the use of fossil fuels will prevail for a long time^{1,2}.

Because in Colombia the costs of buying efficient technology for small and medium-sized companies if they do not have the production required to support these investments, one of the best alternatives is to optimize processes, maintain equipment in use, implement affordable technologies of monitoring and supervision that contribute to maintain the equipment in its best performance and reduce energy losses.

The implementation of digital instrumentation systems³ manages to register efficiently, currents, torque, speed, liquid volumes, volume of flow, vibration, etc. all these indexes allow us to analyze the efficiency of a mechanical system, the response of the instrumentation in the form of low power electrical signals allows to digitize them and then process them, store them and visualize them as the case may be, all this history of events when

*Author for correspondence

analyzing and characterizing them they allow to demonstrate the performance at all times of the machinery in each job and level of demand, for which it is possible to take all the necessary corrections in advance, increase productivity and improve energy expenditure.

This document describes the development process of a SCADA system⁴⁻⁹ on the Labview software, which is a program oriented to perform graphical programming through the interconnection of program blocks, to design a system that allows monitoring in Real time diesel consumption rates of a conventional generator.

2. Description of the Sections of the System

Labview¹⁰ as a software that allows to develop virtual instruments also allows to analyze information for this case instrumentation signals and to give them the treatment to interpret them, likewise it presents functions that allow to have communication of information by serial ports with automation devices.

The development of the application is divided into five sections, the first section is the main interface where the indicators are located, the level and power generation graphs, the second section corresponds to the historical data tables, the third is a section of tools for tank cubing, the fourth section corresponds to the calibration and activation of simulation signals and the fifth section corresponds to the handling and transmission by serial port.

2.1 Main Supervision Section

This is the main section and it shows the status indicators in real time of the levels of each of the tanks, the temperature and the generator's electrical generation (Figure 1), this section also has graphs that are updated to see the behavior of the total level of diesel, electricity generation and consumption, the previous ones with respect to time, this allows practically through the scrolls in the graphs to see a previous behavior.

2.2 Section of Historical Data and Alarms

Registers second to second continuously in tables, the digitized information of the instrumentation elements in the field such as level sensors, temperature sensors and electrical generation. Therefore it is possible to go back in the historical data to see in detail the information acquired while the platform was working and analyze some previous behavior.



Figure 1. Main supervision interface

In this section there is also the history of the alarms that occurred when the indices configured for nominal consumption were exceeded, allowing to observe the moment in time in which they were presented and the level of expenditure in which these levels were exceeded.

2.3 Tank Cubing Section

This section provides a tool to do the cubing of tanks (Figure 2) so that in the field if there are other fuel reserve tanks you can make your capacity estimate or if they are going to be manufactured you have an idea of the dimensions that these should have to house fuel.

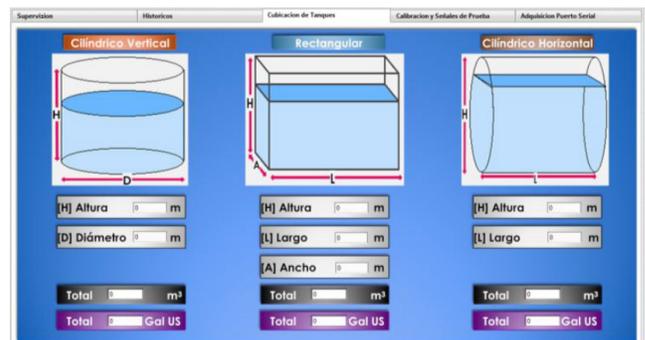


Figure 2. Tank cubing interface

It also avoids that by mistake the configuration section of the tanks on which the data acquisition is being made is used to make analytical calculations of other reservoirs of which it is made half manual.

2.4 Calibration Section and Generation of Test Signals

In this section configuration is given to signals 4 to 20mA acquired for the platform to perform the respective internal calculations to create the cubing of the tanks being

monitored and their level with respect to the instrumentation signal. Likewise, the instrumentation signal is configured for the levels of temperature and electrical generation, the correct configuration between the signals acquired and the operating parameters are those that will give the level of effectiveness of the platform, since this allows the process to In this case, electricity generation and diesel consumption are as real as possible to the process being monitored.

Controls were implemented that create simulated signals which allow to verify the functioning of the system, for these signals it is possible to configure its descent time simulating the discharge process of a diesel tank, it is also possible to simulate the signal coming from a sensor. Temperature and electrical power, these signals vary in the same range as an instrumentation signal as it would in the range of 4 to 20mA.

2.5 Serial Port Configuration Section

In this section you have the controls that allow communication through a serial port, in this case it allows you to open a specific port to receive a frame coming from any device that uses RS232 serial communication (Figure 3), such as a signal concentrator of instrumentation which receive multiple analog instrumentation signals and transmit them digitally in a frame by serial communication.

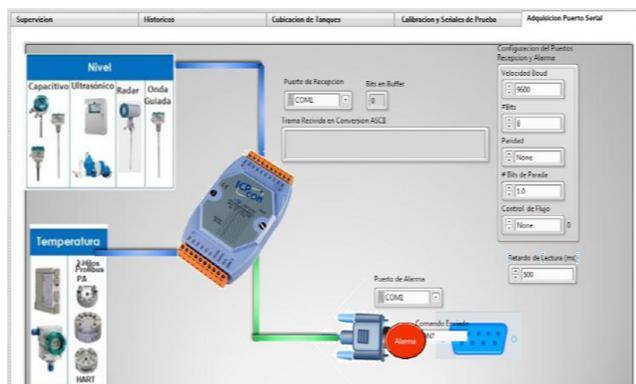


Figure 3. Serial port configuration interface

It also determines the output frame and the serial port that will be used when the Emergency button is pressed, which allows connecting a conventional drive system for power control by SCR, reloading, etc., just by plugging into the port. You can control an external device such as an audible alarm, electro valves, shut down the generator among others.

3. System development

For each phase of the system according to its function within it, it was required to carry out a specific programming and also taking into account that there are sections of the program that intervene in others, such as the configuration section which directly affects the signals reflected in the supervision section.

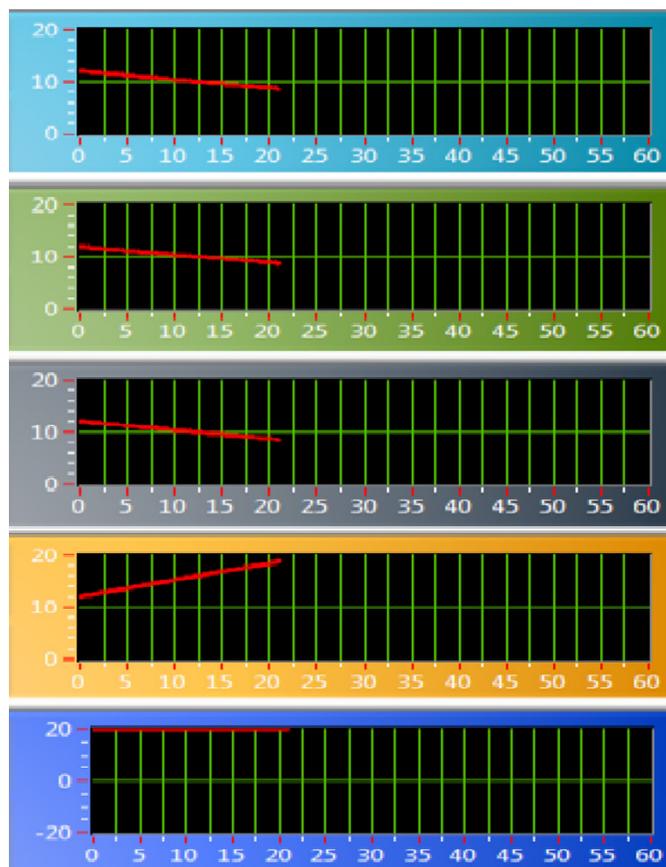


Figure 4. Signal display scopes

3.1 Generation of Simulated Input Signals Simulated Input Signals from 4 to 20mA

In the first instance, taking into account that the system seeks to show the behavior of instrumentation signals, it was found that level sensors independently of their type such as ultrasonic, flotation, radar, among others, at an industrial level the most conventional signals to deliver their measurement are the analog signals 4 to 20mA therefore for this first phase of software similar simulated signals 4 to 20mA amplitude being 4mA when a level instrument detects an empty tank and to a maximum of

20mA when the fluid level reaches the top developed of the tank.

To create the simulated input signals, the program block named *Simulate Signal Express* was used, which at its output generates pre-configured signals in its signal options such as saw tooth, sinusoidal, triangular and DC.

Given that the behavior of a tank is down and therefore likewise the instrument signal is set at block *Simulate Signal Express* signal saw tooth, but since this is up was reversed to have a downward signal that emulates the behavior of the signal from a level sensor.

Additional controls were used which allow from the front panel interface to modify the period of the inverted saw tooth signal to emulate different discharge times of a tank and also amplitude controls were added that allow to give the maximum range from where the signal and the minimum level. To check the behavior of the generated signal, *Scope* blocks (Figure 4) were added, in which the behavior of the simulated signal and its operating ranges are visualized, in order to be able to determine that the simulated input is entering according to what you want it to analyze the system.

Five independent signal blocks were created in order to make it possible to independently simulate the signal from each element of the project's instrumentation, which would be three diesel level sensors, a temperature sensor and an electrical power sensor.

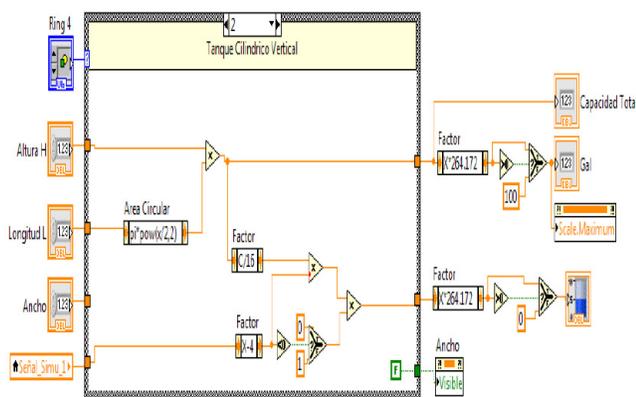


Figure 5. Vertical cylinders measurement program

3.2 Phase of Adaptation, Calibration and Calculation of Tanks and Instrumentation

Bearing in mind that for measurement projects, the instrumentation systems can be of different types, it is required to perform an independent calibration for each of these, where the signal ranges are assigned with respect to the

measurement that is performed as the height of fluid that measures or the temperature, likewise in this stage, it is necessary to consider the cubic size or dimensions of the diesel tanks and their particular shape, with which it will be possible to determine the amount of diesel fuel with respect to the instrumentation signal acquired.

For this particular case there is the opportunity to select between three types of storage tanks which are vertical cylindrical tanks, cylindrical horizontal and rectangular, when selecting the tank type and entering their dimensions the respective measurement schedule is executed.

3.2.1 Program for level Measurement Vertical Cylindrical Tanks

For the measurement of cylindrical tanks, the block programming of Figure 5 was carried out, in which the controls that allow the diameter of its base and its height in meters to be entered for this type of tanks, as shown in (1), with this data its maximum storage capacity is determined¹¹.

$$Volume [m^3] = \pi * r^2 * h \tag{1}$$

Subsequently, the calculation of the current level of diesel that is present in a cylindrical tank is performed, depending on the instrumentation signal, which would come from a level sensor and which varies from 4 to 20mA, analyzing the above was reached (2), which was implemented by means of calculation blocks in the Labview software, where for a 4mA signal a tank level of zero Gallons will be obtained and, depending on the variation of the instrumentation signal, the current level will be in gallons that are in the diesel tank.

$$Measured_Volume [m^3] = \pi * \left(\frac{d}{2}\right)^2 * \frac{h}{16} * (Signal - 4) \tag{2}$$

After making the calculation of (2), multiplied by 264,172 to obtain the volume measured in gallons which is the parameter most used when talking about diesel fuel quantity.

3.2.2 Program for Level Measurement in Rectangular Tanks

For the measurement of this type of tanks it is required to have the length of the height, the length and the width, when entering these dimensions in the program blocks

the system determines in the first instance the total capacity in gallons that will contain the tank, in (3) the equation for cubing this type of tanks is shown.

$$Volume [m^3] = Long * Wdth * \frac{High}{16} * (sgn al - 4) \quad (3)$$

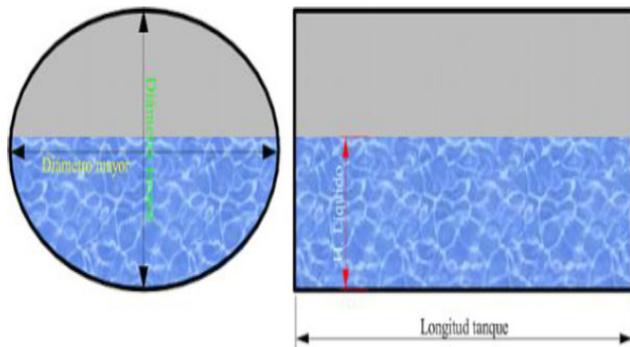


Figure 6. Non-linear variation of diesel volume in horizontal cylinder¹¹

According to the previous cubing it is determined that the variation of height of the fluid is the index that will determine the quantity of fuel and is related to the instrumentation signal of the level sensor from 4 to 20mA, therefore it was determined in (4), where the instrumentation signal acquired is the variable that ends the current volume in cubic meters that is multiplied by the factor 264,172 to show the current volume in gallons.

$$Volume [m^3] = Long * Wdth * \frac{High}{16} * (sgn al - 4) \quad (4)$$

3.2.3 Program for Level Measurement in Horizontal Cylindrical Tanks

Unlike the level measurement¹²⁻¹³ of the aforementioned tanks, the cylindrical lying tank presents greater complexity since the increase of the height of the diesel inside the tank is not proportional to its current volume as shown in Figure 6, therefore in principle the tank cube is performed according to (1), where the diameter was taken as the height and length of the tank, this calculation was configured in the software to determine its maximum diesel capacity in gallons.

To determine the current volume in the tank according to the height of the diesel inside it was used (5), in which with the variation of height the area that is in contact with the fluid of the circular face is determined and multiplied

by the long to thus have the current volume of diesel inside the tank, this calculation was programmed in the software, where also the signal from 4 to 20mA is parameterized with the height to thus have the volume variation with respect to the signal of acquired instrumentation.

$$V = \frac{D^2 * L}{4} * \left(\text{acos} \left(1 - 2 * \frac{H}{D} \right) - \left(1 - 2 * \frac{H}{D} \right) * \sqrt{4 * \frac{H}{D} - 4 * H^2} \right) / D^2 \quad (5)$$

3.2.4 Programming for Temperature Measurement

Bearing in mind that for commercial temperature instrumentation systems usually already bring the electronic compensation that allows them to deliver a linear signal from 4 to 20mA according to the temperature variation, the programming in blocks shown in Figure 7 was carried out using (6) that relates the instrumentation signal linearly and the temperature ranges of the instrument.

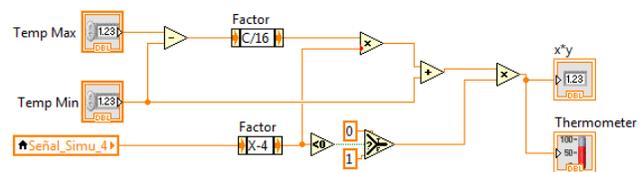


Figure 7. Program in blocks for temperature measurement

$$Measured_Temperature [^{\circ}C] = \frac{TempMax - TempMin}{16} * (Signal - 4) \quad (6)$$

The interface of Figure 8 was created, where the parameters are entered to be processed and the current temperature value is obtained.

3.2.5 Electrical Power Measurement Programming

The measurement of output power is understood to be made by means of transducers that deliver linear instrumentation signal from 4 to 20mA according to their maximum measurement range, therefore the controls were programmed to enter the maximum level of measurable power, the linear calculation process between the acquired signal and the measurement shown was programmed by blocks, with which, for each certain level of acquired signal, its proportional level of electrical power will be reflected.

3.3 Programming Phase and Visual Indicators and Trends

In this stage of programming, visual indicators were developed that will be in the main interface of the opera-

tor and that allows to visualize in a graphic and explicit way the level of the diesel tanks, the temperature and the output power of the generator.

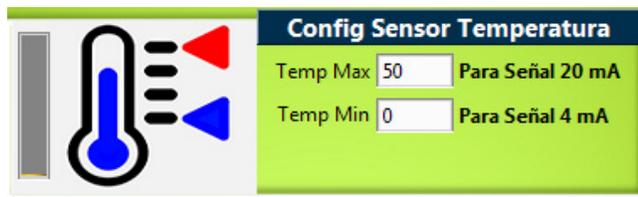


Figure 8. Parameter input window for temperature measurement

Three indicators were created to make the numerical supervision and three vertical visual indicators of the diesel tanks where each one shows in real time the current level, its value comes from the calculations made between the acquired signal and the cubing in the calibration section of the software, allowing observing firsthand the status of each of the diesel tanks that feed the system.

The global volume of diesel is visualized using block programming that realizes the sum of the current level of the three tanks as shown in Figure 9 and the result is shown in a vertical and numerical graphical indicator in the main interface for this global index determine the diesel cost as a function of time.



Figure 9. Graphical interface of status of total diesel

For the temperature display, a thermometer was set in the main interface, with a range between 0 to 100 degrees Celsius whose level is given according to the calculation of temperature made according to the acquired signal.

The visualization of electrical power generated was made with an analog type indicator Figure 10 which fluctuates according to the resulting calculation between the acquired instrumentation signal and the previously performed calibration; in addition there is a numerical indicator in order to see the electrical generation in a timely manner current.

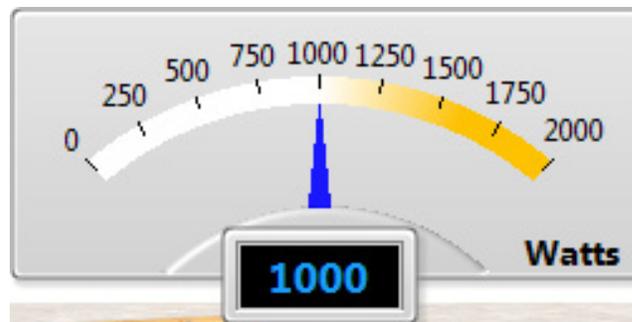


Figure 10. Graphic interface of the level of electrical generation

For the graphic visualization of the electricity generation trend, the block programming was carried out, with which the data of the electric generation and the time in which they were generated are stored, and half a signal plotter it is possible to see the trends of the historical data associated with the electrical production of the generator.

For the programming of the current consumption indicator Figure 11, a comparison between the global diesel levels is made every minute, therefore the value every minute is sent to the numerical indicator of the main interface and is stored in a numerical array to be displayed in Signal graphing and being able to perform the historical verification of the expense for any time.

The nominal consumption per watt is determined by taking the current consumption per minute and dividing it by the electrical power measured at the moment of time in order to determine if the diesel consumption is in accordance with the electrical production of the generator.

3.4 Programming Phase for Capture in Historical Databases

In order to visualize the historical data calculated by the system over time, several tables were programmed which store, second by second, the current value of all the indicators shown by the system, such as tank level, total diesel volume, consumption per minute, electricity generation and time in the time format when it was registered.

3.5 Programming Phase for Serial Port Management

To allow the reading of data from an instrumentation concentrator, the access to the serial port was configured through blocks, where through the user interface the parameters are selected to establish communication through the port, such as speed, number of bits, the delivery, the flow control the port.

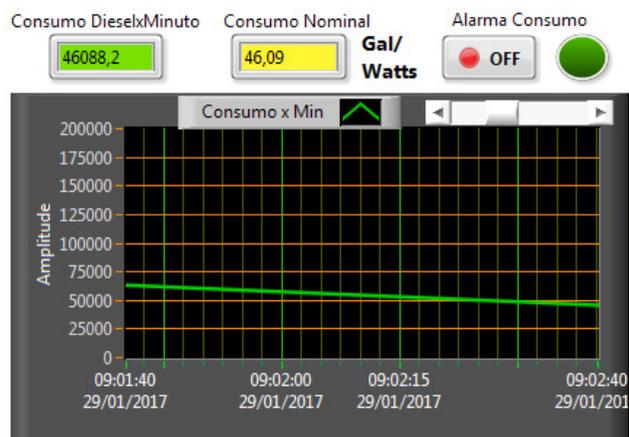


Figure 11. Current consumption supervision interface

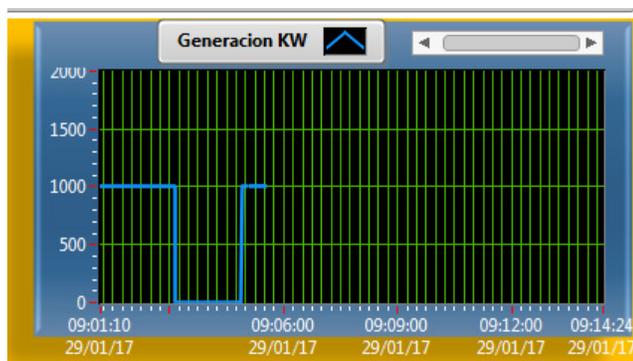


Figure 12. Power generation trend interface

At the input data level these are read in the buffer of the respective port and displayed in the user interface in ASCII format and the data output that is activated from the Stop button in the main user interface sends the characters either through the same port number or another if selected.

4. Analysis of System Operation

The tanks were configured, giving them approximate values to those corresponding to the size of a conventional tank, and a tank of each type was selected and it was validated that the respective cubicle was in accordance with the delivered dimensions, as well as the temperature and temperature signals were parameterized electric power output.

The simulated input signals were activated giving different level ranges and different discharge times for what would be the diesel tanks, as well as the simulated input signals to emulate the variations in temperature and power generation (Figure 12 and Figure 13).

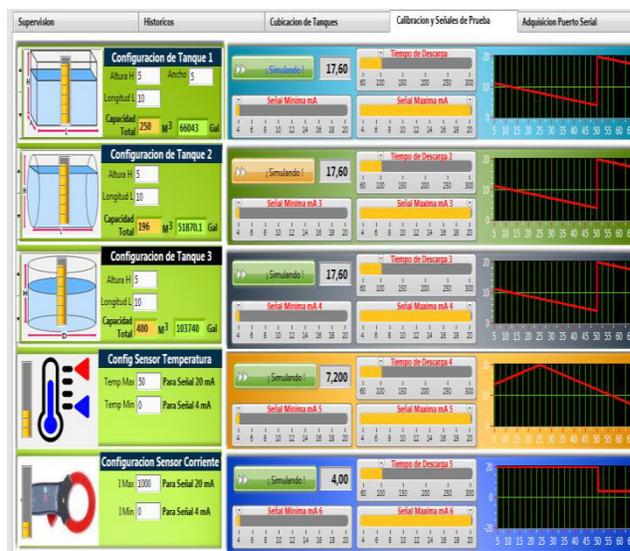


Figure 13. Calibration interface and generation of simulated signals

In the supervision screen, the state calculations are displayed and in the trend graphs the graphs are constructed according to the system execution time, as well as the variation of the level of the diesel tanks according to the configuration of the simulated entries and how the trend graphs vary according to these indicators.

5. Conclusions

The developed system allows making changes in the simulated input signals that allow validating the operation; likewise it could be modified to validate other behaviors of either the diesel tanks as well as the temperature or the electrical generation.

Through the programming in Labview, a SCADA system was developed for the supervision of customized walls and the programmed modules can serve as a basis for the development of other processes that need a personalized process monitoring system.

The developed system demonstrated that conventional equipment such as desktop computers with conventional operating systems can be programmed using software such as Labview to create programs that support automation processes at lower cost and not necessarily less reliable than other specialized automation equipment that Simple industrial processes are high cost.

It demonstrates the importance of active supervision to industrial systems for this case those of energy production because of not having efficiency in its operation there

are economic overruns, mechanical damage and above all environmental damage that will create a detriment to the viability of the industrial process.

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