DATA ACQUISITION SYSTEM AND LOAD CONTROL SYSTEM FOR DIESEL POWER GENERATOR TESTING

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Abstract. *This work describes a data acquisition system developed for diesel power generator fuel consumption testing. The data acquisition system was developed using LabView software. The software and hardware that are integral part of the system are detailed. The main input and output data of the system are described. Typical results produced by the system are presented for tests carried out in a 50 kW diesel power generator. Maximum discrepancies of the results obtained using the developed system from reference tests for exhaust gas temperature, fuel conxumption and load power were below 7%.*

Keywords*: data acquisition, control system, diesel engine, power generation.*

1. INTRODUCTION

Brusamarello and Balbinot (2010) define sensor as a power converter and transducer as a device that converts a signal from a physical form to a corresponding signal of another physical form. A sensor is as a measurement system element that is directly affected by a phenomenon, body or substance that contains a measuring parameter and transducer is used to provide an output signal that has a specific correlation with the input size. Both a sensor and a transducer are measurement system parts. Bolton (1998) says that, in general, measurement systems can be represented as having three elements (Fig. 1):

- transducer, a detection element that produces a signal related to the amount of the variable being detected;
- signal conditioner, which converts the transducer signal into a form in which it may be indicated;
- display or recorder, which enables the signal to be read.

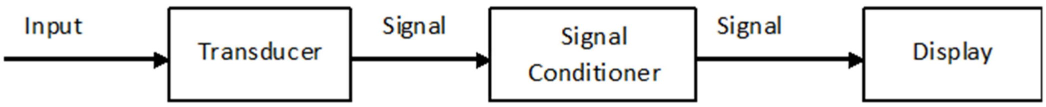

Figure 1. Measurement system elements.

A data acquisition system and a load control system were developed for testing a diesel power generator. The data acquisition software was developed using LabVIEW platform. LabVIEW is an acronym for *Virtual Instrument Engineering Workbench Laboratory*. Produced by National Instruments, is a graphical programming language. The first version appeared in 1986 for Macintosh machines and currently there are also integrated development environments with the Windows operating systems, Linux and Solaris. The application main fields are physical forms measurements, automation and processes control. The programs are built in graphic language called Virtual Instruments (VI) and comprise a front panel and block diagrams containing the code graph program built with data flow diagram for easy handling. The programmer does not need to write any code line. The graphical processes presentation is easy to read and use. An advantage in relation to text-based languages is the ease to create components in parallel. In large projects it is very important to plan thoroughly its structure. LabVIEW presents good interaction with other programs and can transfer data to Excel spreadsheets, for example.

2. MEASURING SYSTEM

The experimental apparatus was constituted by a 50 kW diesel power generator, thermocouples, thermal resistors, thermohygrometer, mass balance, orifice plate, power meter and load system (Fig. 2). The generator electric charge was made by two blocks of 2.5 kW electric resistances, one of 5 kW and four of 10 kW. The applied load could be increased with a minimum step of 2.5 kW. Figure 3 shows the load command circuit. Three control modes have been developed (Fig. 4). In the first mode the operator sets the load manually. In the second mode, the diesel power generator is submitted to a pre-established load sequence. In the third mode a load sequence can be programmed by the operator command.

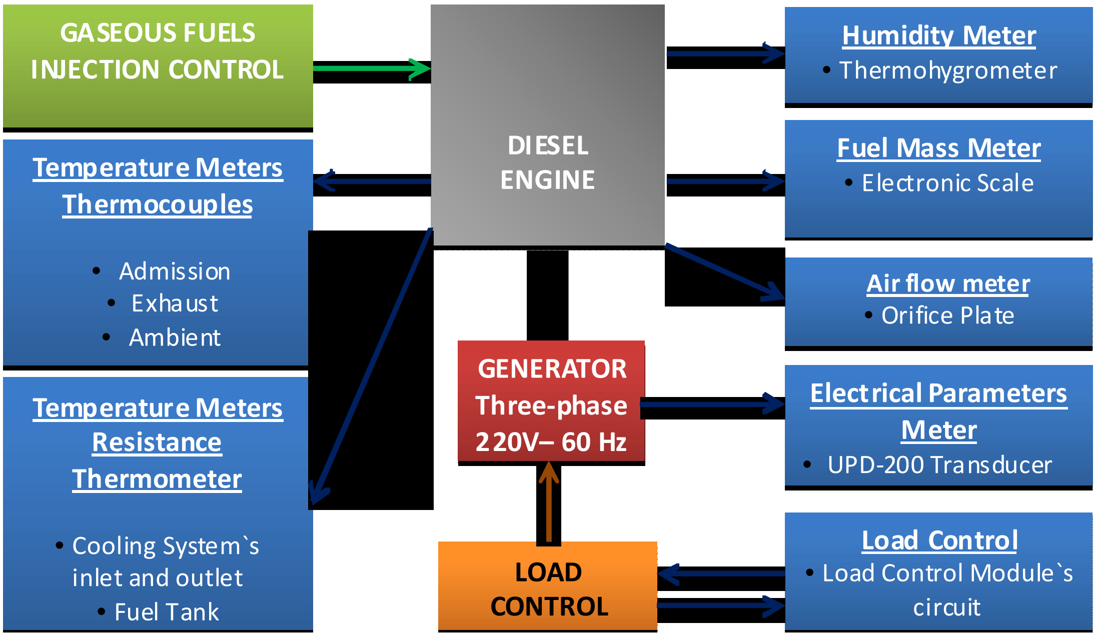

Figure 2. Components of the experimental apparatus.

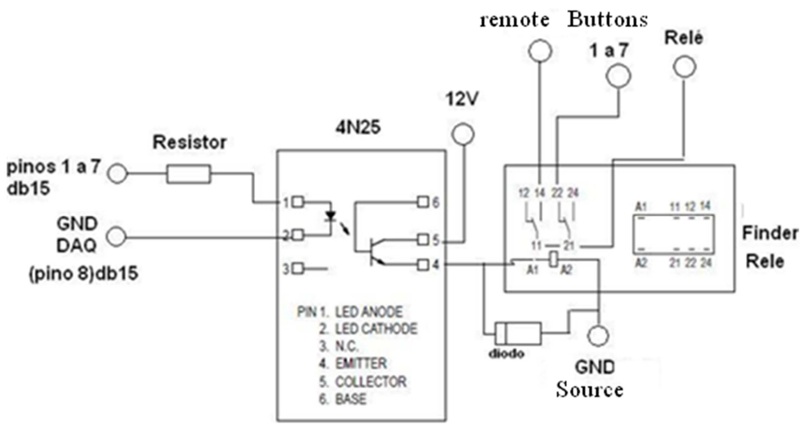

Figure 3. Load control circuit.

Figure 4. Programmable sequence load front panel.

The test room air temperature and humidity were measured using a Thermohygrometer 9406 model manufactured by Delta Ohm. This thermohygrometer uses a capacitive sensor for air humidity measurement and a Pt-100 resistance. The digital data was sent from a serial port to the computer and handled by the LabVIEW software and configured for reading through the Serial Virtual Instrument Software Architecture (VISA). Fuel consumption for each load applied to electric power generator was calculated by the ratio between the mass variation in the fuel tank and the test time. The fuel tank mass was measured by a digital balance Lider model B520. The intake air flow rate was measured using an orifice plate, according to ISO 5167 standard (ISO, 2003).

The UPD-200 (Fig. 5) is a programmable microprocessor and transducer for measurement, calculation and visualization of the main three-phase electrical networks parameter. The UPD-200 has a communication interface RS 485 and MODBUS RTU protocol, that allows for communication with the computer. For connection of this interface with a developed system serial port RS 232 a converter RS 485 to RS 232 was used, manufactured by Analo (Fig. 6). In a three-phase electric power system the electrical energy is given by the equation $P_{3\phi} = \sqrt{3}\, V_f\, I_f \cos\varphi$, where $V_{(f)}$ is the phase voltage (Volt), $I_{(f)}$ is the phase current (Ampere), and $P_{(3\phi)}$ is three-phase electric power (Watt), being φ the lag angle between $V_{(f)}$ and $I_{(f)}$. φ has a value of zero for resistive circuits. Phase currents were transferred to the UPD-200 through current transformers with transformation ratio 200 to 5. The electric power meter communication protocol MODBUS RTU is set with a speed communication 9600 bps, no parity, 1 stop bit, 1 peripheral, and 8 data bits.

Figure 5. UPD-200 microprocessor.

Figure 6. RS 485 to RS 232 **c**onverter**.**

The balance, thermohygrometer and electric power meter (200 UPD) were directly connected to the computer through serial communication ports and the data was accessed by the Labview software. Thermocouple signals were amplified and filtered by the circuits shown by Figs. 7 and 8. The thermo resistor provides current shaped signals that, through a board with resistors, are converted into voltage. All these signals were inserted in the data acquisition board to to convert analog signals into digital signals according to the communication protocol and transferred through a USB cable to the computer. The conditioned signals from the thermocouples and thermal resistors were acquired and processed by the data acquisition board through the program shown by Fig. 9. The experiments could be monitored in real-time via a software interface containing all measurable parameters by the data acquisition system and the load control system (Fig. 10).

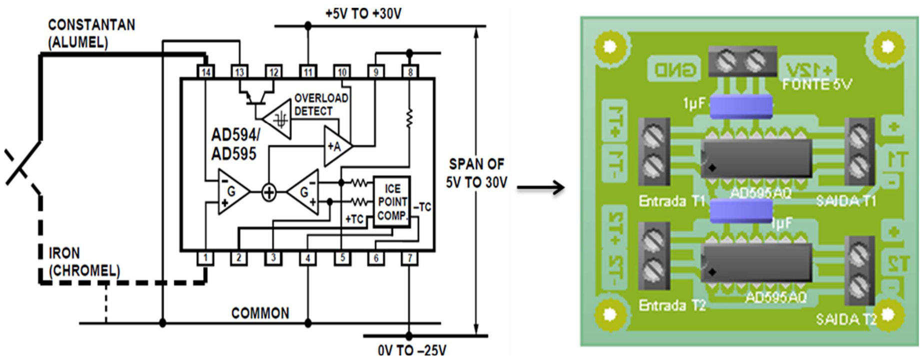

Figure 7. Temperature signal amplifier.

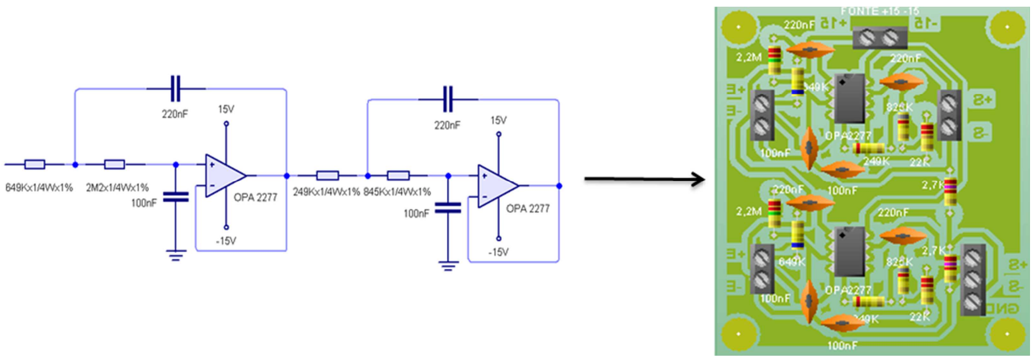

Figure 8. Low pass filter.

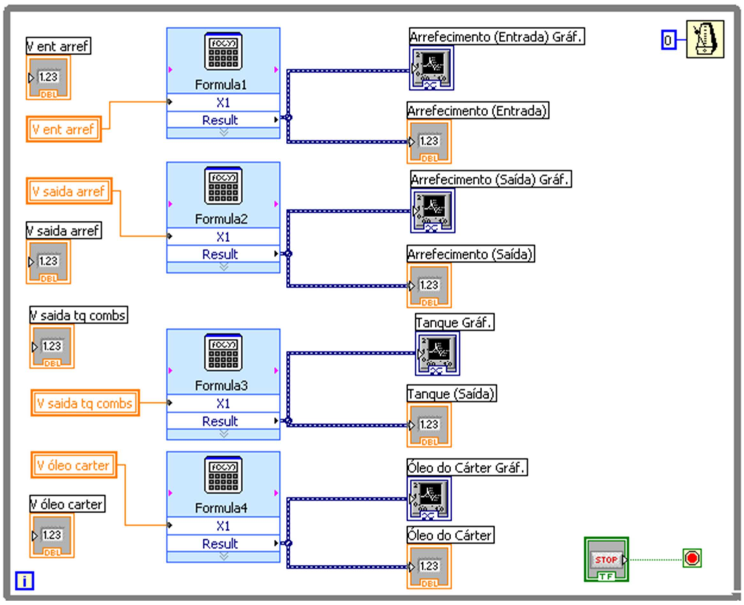

Figure 9.Temperature data acquisition program.

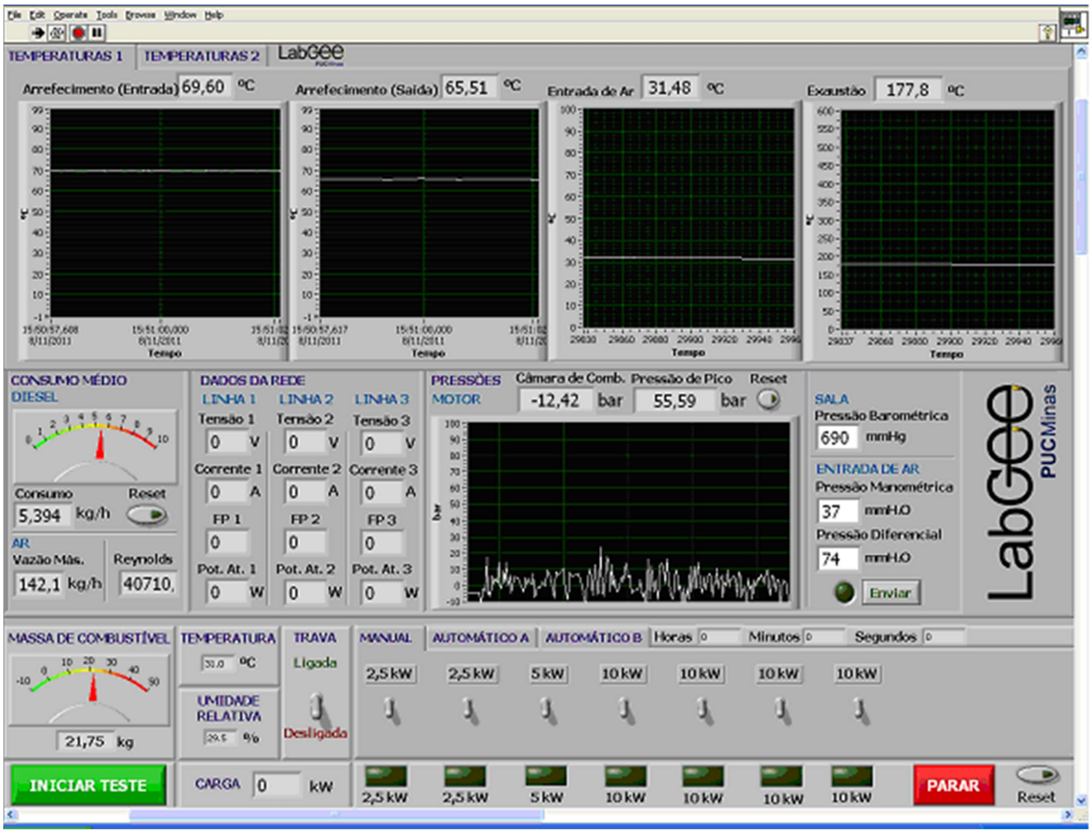

Figure 10. Programmable software interface.

4. DATA ACQUISITION SYSTEM AND CONTROL SYSTEM VALIDATION

Tests were conducted with the load control system and the data acquisition system, and the results were compared with those obtained by Valente (2008). The maximum uncertainty of the measurements, calculated by the methodology described by Kline and McClintock (1953), is shown by Table 1. The exhaust gas temperature data can be seen in Fig. 11. The exhaust gas temperature measured in this work present a minimum difference of 0.34% at 20 kW and a maximum difference of 5.72% at 30 kW in comparison with the measurements performed by Valente (2008). This discrepancy can be explained by the different ambient conditions of the tests, as the exhaust gas temperature is influenced by room temperature, pressure and humidity. Another possible influence was the use of different acquisition equipment, once Valente (2008) used a digital oscillograph Yakogawa model DL 708 to acquire the exhaust gas temperature data in his work. The use of different fuel samples may also have played a role.

In the reference work (Valente, 2008) fuel consumption was determined using a balance with a maximum value of 5 kg and a resolution measuring 0.1 kg. The average of three fuel weight measurements at the beginning and at the end of the test was used to calculate fuel consumption. Figure 12 shows the two measurement methods results. There is a minimum difference of 3.63% in 0.0 kW and maximum of 6.97% in 10 kW. Maximum uncertainty of fuel consumption measurement by SiCCAD-LabGEE is 2.85%. The values compared to electrical power between the two works are shown by Fig. 13. The smallest difference was 2.91% at 10 kW and the largest difference was 3.69% at 30 kW. The maximum uncertainty of power measurement by SiCCAD-LabGEE is 0.05%.

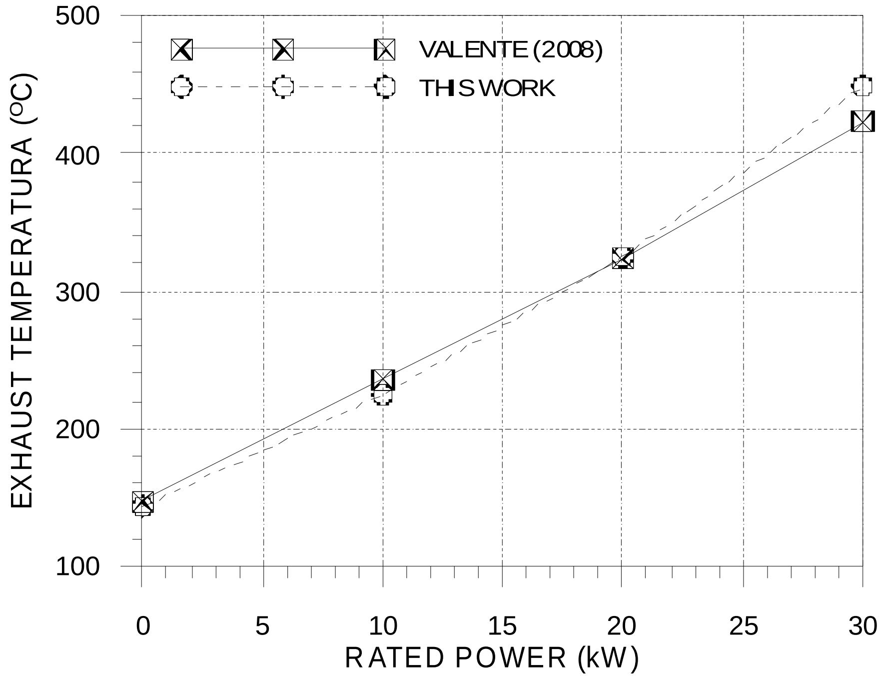

Figure 11. Comparison of exhaust gas temperature variation with load power.

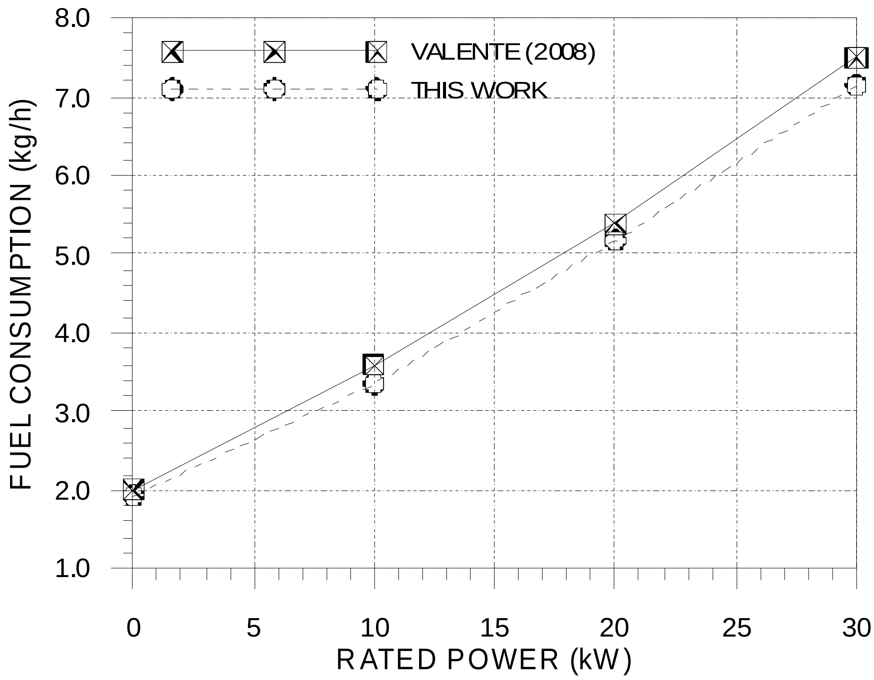

Figure 12. Comparison of fuel consumption variation with load power.

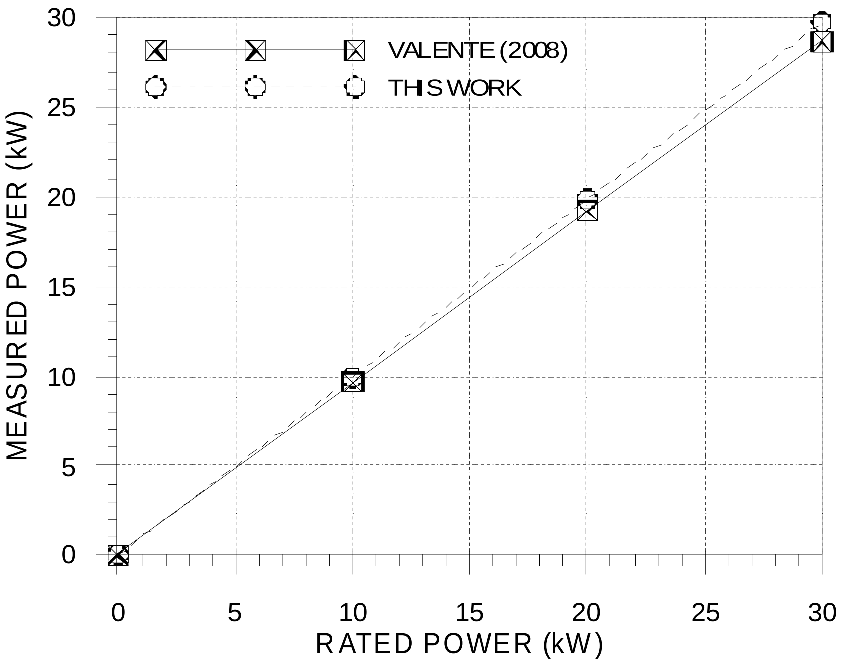

Figure 13. Comparison of measured load power variation with nominal power.

Table 1. Uncertainty of the measurements.

PARAMETER	UNCERTAINTY
Power (kW)	± 0.3
Exhaust gas temperature (°C)	± 4.8
Fuel consumption (kg/h)	± 0.1

5. CONCLUSIONS

A data acquisition system and a load control system have been developed for a diesel power generator testing. System software has been developed based on the LabVIEW platform. The systems have been tested against previous results obtained by Valente (2008) from the same equipment, using manual control and data acquisition. Tests were carried out to compare exhaust gas temperature, fuel consumption and measured load power variation with rated load power. Maximum discrepancies of 5.7%, 7.0% and 3.7% were obtained for exhaust gas temperature, fuel consumption and measured load power, respectively. The differences were attributed to different ambient conditions and equipment used to acquire the data. Overall, the developed system performance was satisfactory.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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8. RESPONSIBILITY NOTICE

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