

Multi-Client Application for Electric Arc Furnaces, using Compact RIO and FPGA

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Abstract — This paper presents a solution design and implementation of a multi-client application as a part of a system for electric arc furnaces (EAF). The same allows reading voltage, current, pressure, digital parameters and, depending of the way they control the movement of electrode essentially making a better use of electrical energy.

Within this scope, this paper shows the development of a distributive multi-client platform to monitor the performance on any PC simultaneously to the control system, by transferring the operating software and installation, which is created in Labview and synthesized in an FPGA, which implement software algorithms in hardware.

The result is a product installed on any computer that connects to the embedded controller (Compact RIO) capable of monitoring and control via an Ethernet network, providing the user with a graphical human interface (HMI).

Keywords: NI Compact RIO, cRIO, FPGA, Embedded Systems, HMI, Labview, EAF, GUI.

I. INTRODUCTION

In the control processes that take place in real life is mandatory to meet the design goals, in the case of siderurgical industrial automation like this; those are to better dispersion, to lower power consumption and to optimize costs. But as important, is to know the status of the different variables of the process, and to do it from anywhere in the world, is a factor that distinguishes between common industrial processes, and even more it is, to do all the programming in a single embedded automation device.

In the project referred to this work, emerged the need to explore the alternatives which allow connectivity, such as the TCP / IP (Transmission Control Protocol / Internet Protocol) or UDP (User Datagram Protocol) protocols, to provide access to subsystems via HMI and, to manage (at a lower layer of the protocol stack) the underlying hardware platform that runs it, i.e. their modularization.



Fig 1. NI compact RIO

The device that manages the control, command and also support the platform is the embedded NI Compact RIO (Fig.1), which is program with Labview (acronym for Virtual Instrumentation Laboratory Engineering Workbench), on which is an FPGA (reconfigurable Field-Programmable Gate Array), free programmable, which allows to run potential combinational logic and high-density concurrent processes fast enough. The ability to reconfigure the FPGA (Xilinx - Virtex V) is the center of the architecture of the embedded system in NI Compact RIO (cRIO) [9].

The objective of the final program, is to use the cRIO for synthesizing control functions, database, HMI, combinational logic and digital processing, creating a Multi-Client system on the same platform that performs the control process of automation, i.e. the same device that performs control loops, real-time calculations, digital processing, resorting the FPGA and embedded systems to synthesize hardware.

One challenge that solves is the convergence of different technology systems that require multiple control devices into a single integrating device PAC. (Fig. 2) [13] (Programmable Automation Controller), which communicates using open network protocols such as TCP / IP or Modbus Plus serial ports.

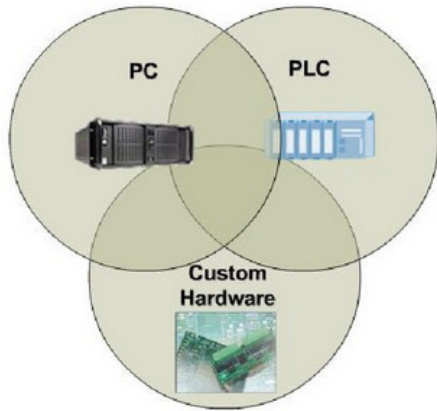


Fig. 2 Current control technology to convert PAC

Another challenge that successfully resolves the proposed design is the implementation of the solution in Labview, most profoundly, is synthesized in VHDL code (Hardware Description Language), and then allowing via an GUI (acronym for Graphical User Interface) his use for human technical operators inside the factory in a user friendly way. (Fig 3).

The control software is transportable in its client version to any PC and allows constant monitoring of furnace control system remotely, including all calculations, functions in time or frequency diagram analysis.

The scope of the project, require that this should be done under strict considerations and stringent quality requirements, schedules and costs, clearly specified.

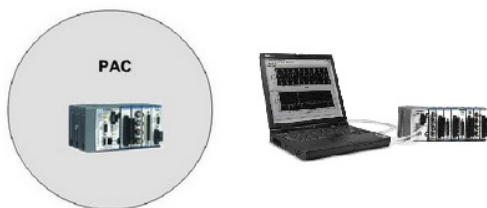


Fig. 3 Compact RIO GUI connection over Ethernet

II. DEVELOPMENT AND APPLICATION MODULE EMBEDDED USING LABVIEW

On the basis of software, it was used for the development “Labview”, proprietary software from National Instrument (NI), which has the advantage of easy programming, simple hardware configuration and high external acquisition speed [1].

After selecting the platform, the remaining hardware and software components were developed involving:

- Design of the hardware platform according to the

requirements of the national steel and siderurgical industry.

- Definition and choice of communication protocol for multi-remote application, in this case TCP / IP.
- Design of Software Platform programmed in Labview 2009, creating the modes “Master” and “Client or user”.
- Commissioning and performance testing in Steel Refining Furnaces.

a) General Architecture

Fig. 2 shows the general architecture of the application running on the system which applies the multi-client embedded platform.

Over the platform “cRIO-9014” is embedded the software done on Labview, and then synthesized into VHDL code. (Fig.5, 9).

The code that includes the logical and mathematical operation for controlling is the same used for performing a multiclient communication, this presents a state for the art technology for the steel making industry.

b) Synthesis of Code

During the synthesis process, code data is obtained from the cRIO (Fig. 5, 6), indicating that the conversion from a Labview code interpreted by the FPGA code is being carried out, this process has different length time, which depends on the complexity of the code developed.

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Related source file is "c:/NI\FPGA-1/srvr\mp\LOCALH-1\TE00DF-1/RegisterAccess32.vhd".
WARNING:387:247 - Input <MLOADD<1>0>> is never used. This port will be preserved and
Found finite state machine <FSM_7> for signal <mwritestate>.
-----
States          4
Transitions    8
Inputs         3
Outputs        4
Clock          MiteClk (rising_edge)
Reset          #Miterreset<0> (positive)
Reset type     asynchronous
Reset state    idle
Power Up State idle
Encoding       automatic
Implementation automatic

Found finite state machine <FSM_8> for signal <ReadState>.
-----
States          3
Transitions    7
Inputs         3
Outputs        3
Clock          MiteClk (rising_edge)
Reset          #Miterreset<0> (positive)
Reset type     asynchronous
Reset state    idle
Power Up State idle
Encoding       automatic
Implementation automatic

Found 1-bit register for signal <MRegPortIn.Rd<0>>.
Found 1-bit register for signal <MRegPortIn.Wt<0>>.
Found 16-bit up counter for signal <MCount>.
Found 32-bit register for signal <MIODataOutReg>.
Found 1-bit register for signal <MReadIOReady<0>>.
Found 1-bit register for signal <MWriteIOReady<0>>.
Summary:
Inferred 2 Finite State Machine(s).
Inferred 1 Counter(s).
Inferred 36 D-type Flip-Flop(s).
Unit <RegisterAccess32> synthesized.

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Fig 5. Data Summary

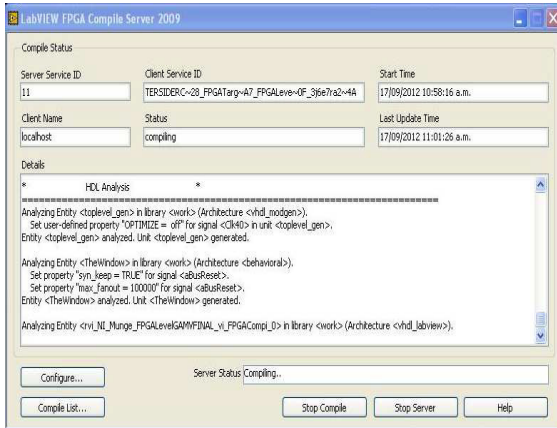


Fig 6. Processes running Compilation

Digital processing techniques have been introduced using FPGA in a wide range. It is always competent to complete all the processes and analyze measurement task by using Labview graphical programming ideas, data flow and execution, [5] which simplifies the process.

c) Application Front View

In Fig. 7 it shows only the front end view of the application. The system shows everything that happens in the embedded controller, control actions, settings, digital inputs, and analog outputs of the same type or, RMS signals, FFT, THD.

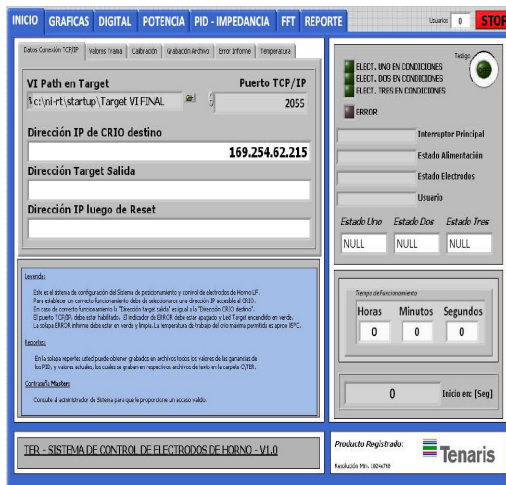


Fig. 7. Panel Frontal

d) Development of multi-client architecture

To make the application work as multi-client is necessary to manage each of the users (clients) dynamically, as each client connects there is a consequent consumption of memory and computational resources which must be managed to deliver bandwidth, the bandwidth generated by client should be able to be returned to the system once the user disconnects, operating dynamically all the time.

The system is designed to give extreme robustness, reliability and energy efficiency. It is believe that a system based on FPGA hardware can be synthesized and achieve temporal precision measurements of the critical component of 25 ns [12].

In turn, there should only be one person running as an administrator (or master) that controls the regulatory system calibration, the reference master must always be connected to flow parameters configuration, if it is off, as it would a client anywhere in the world, that user will only see what happens in the electrode regulation system, but it can not change the control parameters e.g. PID setpoint or constants K_i , K_p , K_d .

Fig. 8 is the one that takes care of adding user connections based on external requirements, which are detected multiplexándolos listening port and correspondingly, also when the user disconnects the connection closes, returning width memory and bands requested.

Then, as the Compact RIO is based on FPGA architecture, algorithms can be implemented in embedded software instead of hardware, which also provides a benefit of synchronization and temporal adjustment compared with common processor [6]. Furthermore, the multi-client system is based on quick decisions and concurrent multitasking typical of FPGA, whose only limitation is the inability to work in floating point [10].

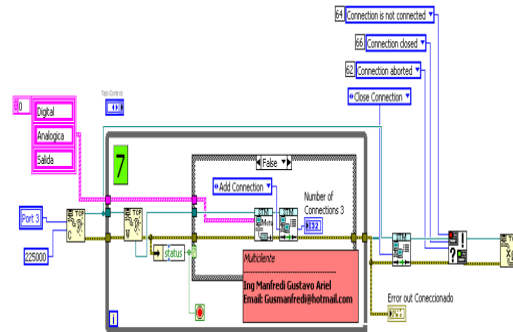


Fig 8. Dynamic allocation of users

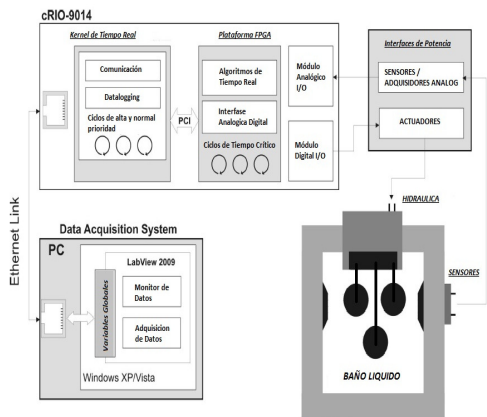


Fig 9. General Architecture Control System

IV. VALIDATION AND VERIFICATION

The validation and verification (V & V) design requires special considerations. At verification level every unitarily particular interface is reviewed, voltage levels, currents, harmonic distortion, dispersion of current value, ignition time, active, reactive and apparent power, and so on, which are stringent and constitute the success or failure of the system.

For testing at unit level the receiving commands, the same excitations were simulated with different impulses types, and changed both digital (on / off) and analog waveform (amplitude, frequency and phase) by a brand HP function generator model 3312A and Texas Instrument digital Simulator.

Subsequently, it was followed with the integration with the real system to verify the data collection from the launcher, verifying the objectives were completed.

Also it was tested the software with maximum settling on Windows 2000 onward as portable installer from a USB flash drive, with good results since all waveforms were identically and only resolution of the monitor problems were encountered.

Field tests were conducted, testing the control system and simultaneous monitoring from steelworks and engineering management, both being several hundred meters away from each other.

Test results were documented and included in the documentation of the system, as a result user manual.

Integration with and industrial PC is also solved with a criterion of verification because the final product is delivered on with a panel-type *Touch screen* PC with Windows embedded owns by NI, and was also

checked the seamless connectivity between the embedded platform under development and the simulator / real control steelmaking plant.

Integrating a final detail, such as having immediate value memory consumption has been scheduled for a later stage of the project and has not been completed at the time of making this publication.

V. PROJECT SUMMARY

The total duration of the project involved about 8 months of work from the definition of system-level requirements, to the conception of a deliverable item, which this paper is a part off.

The approach meets all stages of a cycle iterative live stage type, including requirements, design, construction, testing stages, hardware and software integration and validation.

VI. CONCLUSIONS

This work reflects the creation of a multi-client platform embedded, as part of the development of an improved control system for control an electric arc furnace (EAF) for steel casting.

This type of development appeals to the simplicity of Labview programming environment to create a user interface. The development process is supported in software engineering practices [7] established cycle such as requirements, design stages, establishing baseline configuration and inspections confirming the usefulness of these techniques in the development of embedded systems of this complexity . The hypothesis is confirmed regarding the relative advantages of the selected platform in compare of development based on functionally equivalent conventional architectures. These advantages are in areas such as integration capabilities of hardware and software as an integrated solution and the possibility of flexible firmware update, which transforms into a modular structure developed, tolerant to changing requirements.

An advantage of the design was, developed in a friendly programming environment based on Labview language structures, which allowed the technology to address a learning curve modest compared to what would have been necessary to achieve the application directly to VHDL without previous systetization in Labview.

Also, the systetization of several hardware components such as conditioners, actuators, analog and digital acquisitions under one manufacturer (NI), eliminates incompatibilities, delivering results in a considerable reduction in size compared to applications with electrical and control panel separately, with a logical consequence of reducing

errors, and increasing the ease of detection thereof.

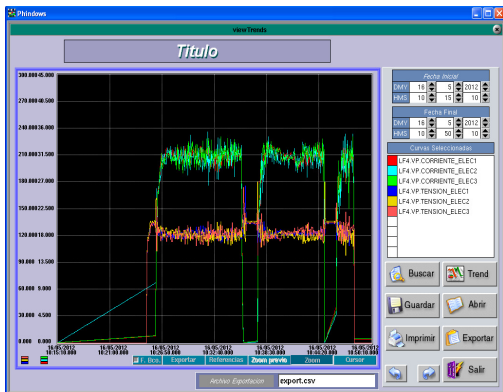


Fig. 12. Normal current dispersion

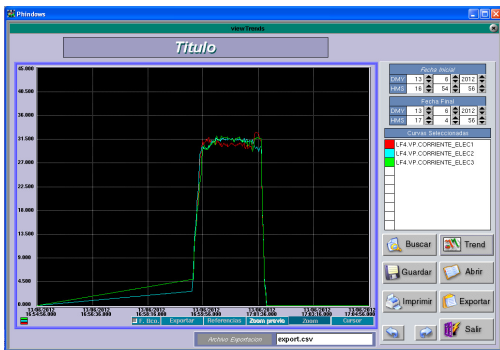


Fig. 13. Improved current dispersion

Following the implementation of the PAC based on FPGA embedded instead of the conventional control system based on PLC (Programmable Logic Controller) was obtained an improved of the current dispersion (Fig. 12 and 13), leading a power savings of approximately 15%, improving therefore the ignition time. Studies were conducted with the system owner level 2 "Phwindows" from Tenaris Siderca [14].

The availability of large numbers of examples, application notes and manufacturer's manuals provided a blueprint for this development.

Future work will lead to the integration of the control system engineering with model based predictive control (MBPC) using Matlab (short for Matrix Laboratory, "**Matrix Laboratory**") and update the embedded software of each module according to requirements for each subsystem and digital / analog (PID, acquirer, etc) integrated.

The final integration is undated, as it is expected a new financial year of the company to assign hours and diagramming an itinerary.

REFERENCES

- [1] Image Processing Based on Seamless Integration Technology Between Lab VIEW and MATLAB - 2010 International Conference on Information, Networking and Automation (ICINA). Modeling and Control of an Electric Arc Furnace -Radu Bălan, Vistrian Mătieș, Olimpiu Hancu, Sergiu Stan, Lăpușan Ciprian
- [2] Mechatronics Department, Faculty of Mechanic
- [3] Available www.ni.com/compactrio/esa
- [4] Available www.ni.com/labview/esa
- [5] Alex See, "Utilizing Labview for data acquisition and analysis for a 13 weeks undergraduate course", American Soc.Eng. Edu. Annual Conference Proceedings, (2004), session no.2220.
- [6] Design of Compact RIO-Based acquisition System Tao Lin. Yongxing Xie, Jing Tan Dept. of Controlling Naval Aeronautical and Astronautical University.
- [7] Metodologías Ágiles en el Desarrollo de Software José H. Canós, Patricio Letelier y M^a Carmen Penadés DSIC -Universidad Politécnica de Valencia.
- [8] "Distributed Application Architecture". Sun Microsystems. Retrieved 2009-06-16.
- [9] Li Meng, Jin Shijun, "Design and implementation of strain acquisition system based on Compact RIO," Research and Development, vol. 26, no. 3, pp.29-31, 55, 2007.
- [10] Carroll Dase, Jeannie Sullivan falcon, Brain Maccleery, "Motorcycle Control Prototyping Using an FPGA-Based Embedded Control System," IEEE Control Systems Magazine, pp.17-21, Oct. 2006.
- [11] Real-Time Control of Active Ankle Foot Orthosis. H.S, V.I.George Department of Electronics & Communication Manipal Institute of Technology, Manipal University Manipal, India
- [12] *National Instruments* [online]. c2010 [cit. 2010- 03-14]. FPGAs - Under the Hood. Desde link de Internet [www: http://zone.ni.com/devzone/cda/tut/p/id/6983](http://zone.ni.com/devzone/cda/tut/p/id/6983).
- [13] Desarrollo de SCADAs con conectividad a PLCs y PAC. Gustavo Valdes. Technical Marketing Engenier NI México Academic Days 2010.
- [14] Tenaris Siderca es una empresa metalúrgica dependiente del Grupo argentino Techint.

