BEYOND THE LIMITS OF CENTRALIZED/DISTRIBUTED CONTROLS: NEW ANSALDO SISTEMI INDUSTRIALI SOLUTIONS FOR ROLLING MILL PROCESS CONTROL[1]

Brocca Claudio[2]
Comisso Stefano[3]
Maule Zeno[4]

Abstract

A new family of products especially designed for automation and electrical drive control is here introduced. By means of a single hardware platform and real time IEC 61131-3 PLC programming it's now possible to integrate the control for both AC and DC motors with complex and demanding process control functions, e.g. flying shears, mill references cascade, loop and tension controls, impact drop compensation and so on. New generation processors and reconfigurable FPGA are the essential elements of such powerful and compact solution, able to satisfy custom plant necessities. By means of real-time drive interfaces based on Ethernet, or more traditional fieldbuses, it's possible to distribute in the plant technological functions at lower costs, minimizing the cabling and reducing at the same time the complexity of any external automation controller. Designed adopting all last technological standards, the new control system integrates advanced functions for motor speed and torque regulation together with dedicated software libraries for process control, particularly useful in Rolling Mills. Its modularity and openness allow providing solutions from the stand-alone application (motor drive and machine control) to the overall management of a plant (distributed process control), with easy integration with the pre-existing automation. Some application examples will be explained.

Key words: Electrical drives; Automation; Process control; Flying shears.

1 *Technical contribution to 44th Rolling Seminar – Processes, Rolled and Coated Products, October 16 to 19, 2007, Campos do Jordão – SP, Brazil.*

2 *Product Development Manager, Industrial Systems and Automation, ASI Ansaldo Sistemi Industriali SpA - ITALY*

3 *Sales Area Manager, Industrial Systems and Automation, ASI Ansaldo Sistemi Industriali SpA - ITALY*

4 *Control Systems Designer, Industrial Systems and Automation, ASI Ansaldo Sistemi Industriali SpA - ITALY*

Project goal

Last trends in the field of information technology applied to automation are the consequence of two fundamental aspects with great influence in the development of new products:

- large computation capabilities of the new digital signal processors,
- large communication potentialities in terms of transfer rate and amount of data exchanged in the network.

These fundamental changes are slowly moving the edge of automation systems (this is true in particular for process controllers) towards distributed control systems able to interact in an independent way with the external environment (see figure 1).

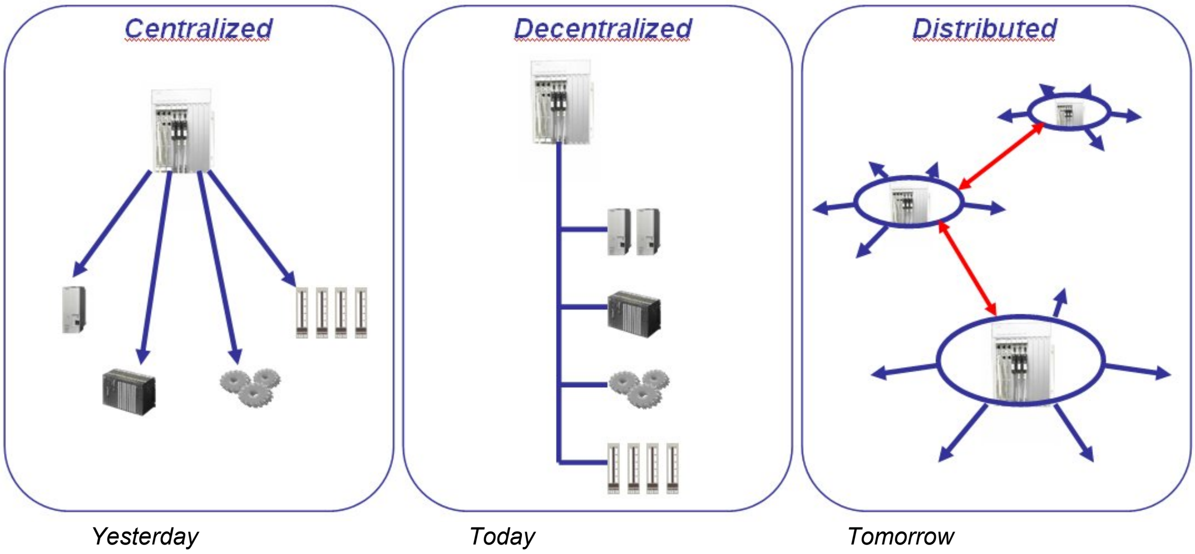

Figure 1 – Evolution of control platforms from centralized to distributed

In the control of industrial processes the drives, which regulate the movements of electrical motors, perform the "operating" part of the system and they are usually considered as simple actuators to obtain the given speed and/or position (servo) profiles.

The algorithms developed for the control of drives, in particular for vector control of AC motors, are well established, even if very sophisticated and demanding a noticeable computing resources to satisfy functions as current vector control, flux regulation, sensorless estimations and so on.

The project "*SYSTEM*" was born with this background and with the purpose to consider, as a consequence of the technological changes in action in the field of microprocessors and communications, the potential role of a new generation family of drives inside the structure of automation for the control of the industrial processes.

It was therefore fixed, in phase of specification, to define the requirements of the system on the basis of 3 fundamental objectives:

- To increase the performances of the control
- To simplify and improve the activities correlated to the use of the product
- To re-design the interaction with the external world and particularly with the plant automation

The activities related to the 2 first mentioned points, even if important for the general development of the product, are not considered here.
It's the third point that defines in a clear way and remarks the identity of the *SYSTEM* platform explained hereafter.
For this reason the design of a new drive control turned into the development of a new platform with strong characteristics of "distributed process controller", with the following main requirements:

1. Re-designing the availability of communication interfaces
2. Giving a direct programmability of the drive by means of development tools IEC61131-3 compliant
3. Providing application libraries with tailored and dedicated functions
4. Allowing a direct visibility of the drive inside the automation structure.

The new control platform can be suitable in substitution of the existing families of drives in low voltage series GT for the control of motors in alternating current for supply voltages from 380Vac to 690Vac and 930 Vdc (in DC bus) and for rated powers from a few KW up to around 6 MW.
Moreover a parallel project is engaged to expand the use of the same platform in the field of Medium Voltage drives for TN family series (3 levels neutral point clamped) for supply voltages up to 6,6 kV and rated powers up to around 12 MW.

Hardware and software architecture description
The control card has been realized through a dual processor architecture to keep separated the critical converter control functions from the overall drive communication and automation tasks.

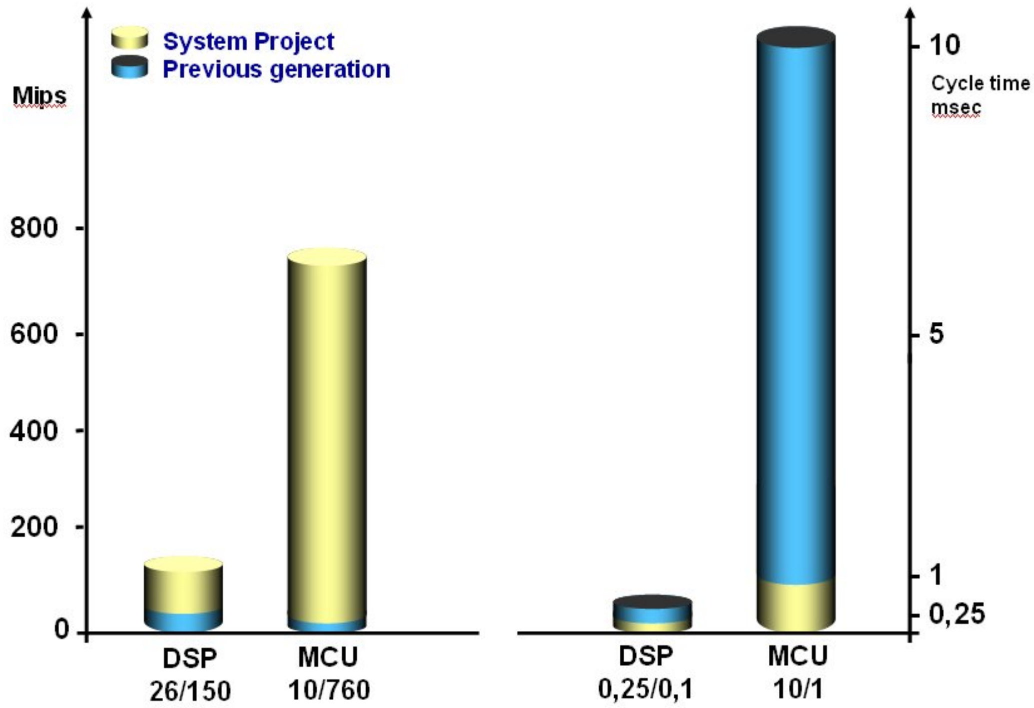

Figure 2 – Comparison of performances (left - in million of instructions per second) and software execution time (right - in milliseconds) for the new control card and the previous used in the GT series

For the control of the drive the choice of the processor was addressed to a highly integrated and high-performance DSP for demanding control applications and in particular for motion control.

For the automation part a microcontroller with PowerPC core has been selected, with a rich set of peripheral functions focused on communications and systems integration.
As shown in Figure 2, as a confirmation of the design choices, the increase in terms of performances in comparison to the previous card is very meaningful for the DSP part (almost 6 times faster), motivated by the choice of a component of last generation, while it is resulting extremely high for the Microcontroller part (76 times faster) because of the different and powerful typology.

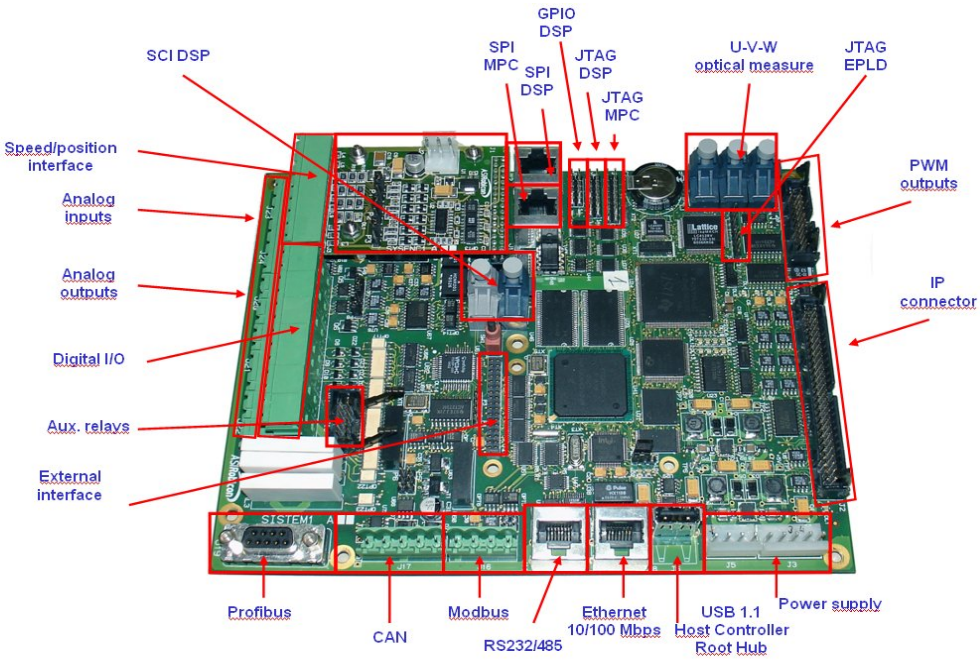

Figure 3 – Photo of the control card and connectors description

The communication architecture was developed on the basis of the following considerations:

1. Openness of the platform to Ethernet networks for centralized management of drives (independently from the fieldbus connection)
2. Increase of serial connections to give the availability for a simultaneous use of the resources from keypads or operating panels
3. Realization of a local Master fieldbus for I/O management purposes to be placed as a complement of the usual plant Slave fieldbus necessary as automation interface
4. Availability of a wireless communication interface
5. Link to other *SYSTEM* cards in Master-Slave configuration (electrical shaft configuration, finishing blocks)
6. Use of memory card with USB or dedicate interface (SD)

To complete the on-board availability in terms of communication openness a Profichip device has been connected to the microcontroller, giving altogether the following communication interfaces:

- 3 asynchronous serial ports RS232/485 (ANSI + Modbus RTU + diagnostics)
- 1 serial port dedicated for wireless link (ZigBee) or Anybus interface
- 1 CAN (CANopen or DeviceNet)
- 1 Profibus DP V2 Slave
- 1 Ethernet 10/100

- 1 USB host controller
- 2 SPI Serial Peripheral Interface (synchronous bus)
- 1 SCI Serial Communications Interface (asynchronous bus)

As a consequence of the dual processors hardware solution, the software architecture results obviously more complex; data exchange between them happens contemporarily with a mechanism of Dual Port RAM (for variables, parameters and tracing) and with a fast synchronous connection (for diagnostics, commands, download / upload firmware).

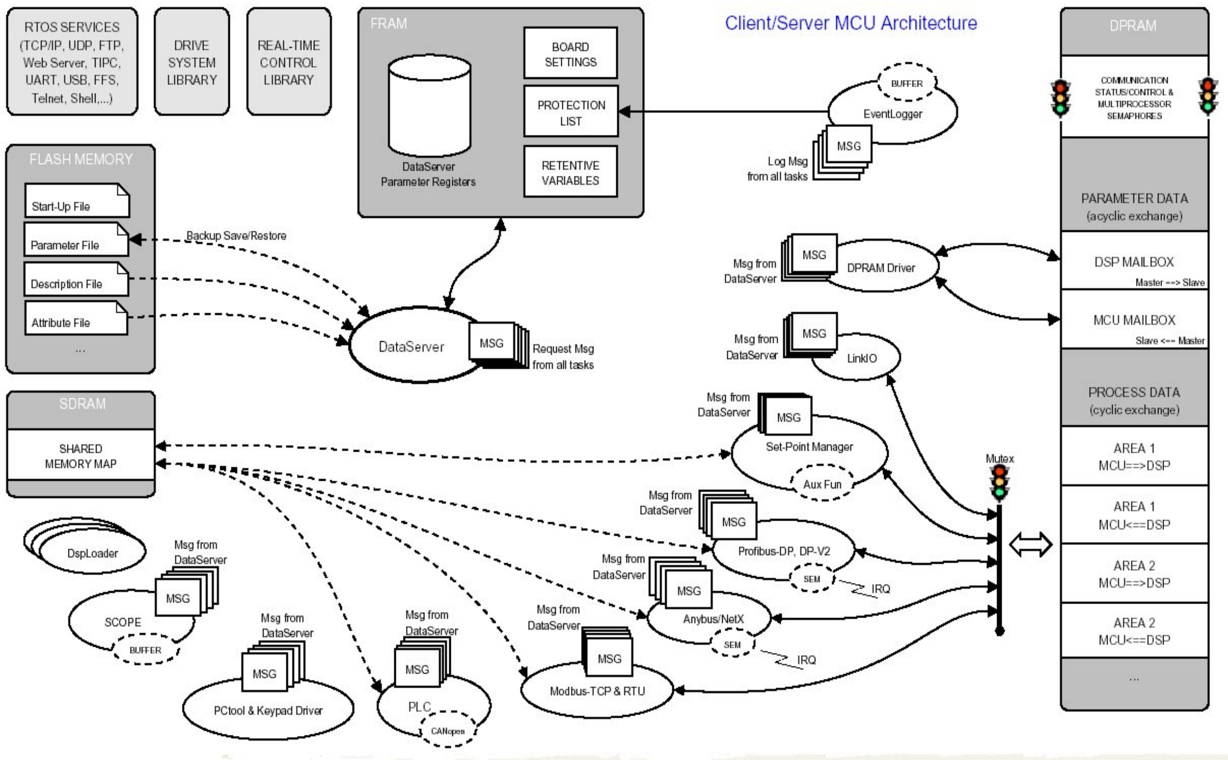

Figure 4 – MCU software architecture with communication tasks management

Figure 4 shows the software architecture and refers to the MCU part (DSP is not visible here; the link with the DSP is indicated as DPRAM in the right part of the figure). The MCU software is based on a preemptive and multitasking real-time operating system; the DOS file system is built on a flash memory and gives a simple and immediate way to access the card via standard FTP and TCP/IP connections to perform operations for configuration and diagnostics.

The main task of the MCU is the DataServer (in Figure 4, to the centre). It has the assignment to manage the drive data access from all other tasks: any single Read/Write request is delivered through messages, which are buffered and sequentially served by the Server. All the fast process variables, generated and used by the DSP, are directly accessed by the single tasks through semaphoring techniques with the purpose to minimize the time delay and assuring data consistency.

Function libraries

The *SYSTEM* software comprises a large quantity of macro functions gathered into libraries. These functions just require a simple parameterization to be directly activated through the engineering tools; in addition they are available for a direct call from both C/C++ and PLC tasks.

- Standard Macro Functions: It's possible to quickly enable these functions through dedicated parameters and commands. Such functions allow customizing the drive to satisfy specific needs.

- Fixed Speed Preset
- Motor Digital Potentiometer
- Speed command loss
- Critical Speed Avoidance
- Ramps
- Jog
- VDC Rollback
- Current Rollback
- Motor Overload thermal protection
- Input Single Phasing
- VDC Undervoltage Ride Through
- Flying Restart
- Energy Saver
- External PID Regulator
- Speed deviation
- Free Run Stop
- Fast Stop (Emergency Stop)
- AutoReset & Restart
- Pulsed Start Stop
- Auto On / Off
- DC Braking
- Speed External Limits
- Underload
- Loss Of Output Phase
- Torque Control
- Torque Limits Control
- Motor Stall
- Torque Overboost
- Trace Settings
- Current Oscillation Compensation

- Advanced Macro functions: these functions are managed as the previous ones but normally refer to specific applications whose effects involve also the internal control

- Helper
- Pope
- Drooping
- Crane control
- PTC/NTC
- Safety override
- Diameter control (speed control with loop dancer)
- Electric shaft

- Automation functions: these functions are not related with the control part of the drive and only deal with process automation. In some cases they need hardware extensions or dedicated plug-in.

- Minimum tension control
- Tension Regulator With Load Cells
- Loop control
- Thickness control (reel control)
- Impact drop compensation
- Flying shear (more versions)

To allow the system to perform functions which require additional specific hardware or extremely high performances the control board is completed by a subset of optional plug-in modules. The easy way to interface complex devices such as FPGA (for instance Spartan or Virtex for the realization of the “flying shear” function) or other microprocessors (for instance NetX for the realization of EtherCAT Master) theoretically allows to develop any real-time application directly on the drive.

Internal PLC

As further step in the development, PLC programming has been therefore implemented; this function is the base for the development of user applications directly inside the card.

This functionality has been realized using open and commercial PLC software that is one of the most powerful IEC 61131-3 programming tools. All five programming languages of the standard are supported and the result is the production of fast native machine code for the MCU side of the card.

This solution combines the easy handling of PLC programming systems with the interoperability necessary to guarantee a simple and direct use in the automation environment.

The PLC program makes use of standard blocks to connect with the internal Server, resulting in a transparent data access for the end user. For example, process data, drive parameters and configurable I/O can be processed and finally shared between tasks with easy variables assignment or calls to libraries functions.

In addition to the functions previously listed in the libraries it is therefore possible to develop PLC functions tailored for specific applications.

Integrated automation

One of the most important features of the *SYSTEM* platform is its easy integration with the plant automation, and the consequent availability for new process control solutions.

Such solutions are scalable on the application and interact through standard communication channels with the most popular programmable logic controllers and SCADA (via OPC, DDE, XML, HTML…).

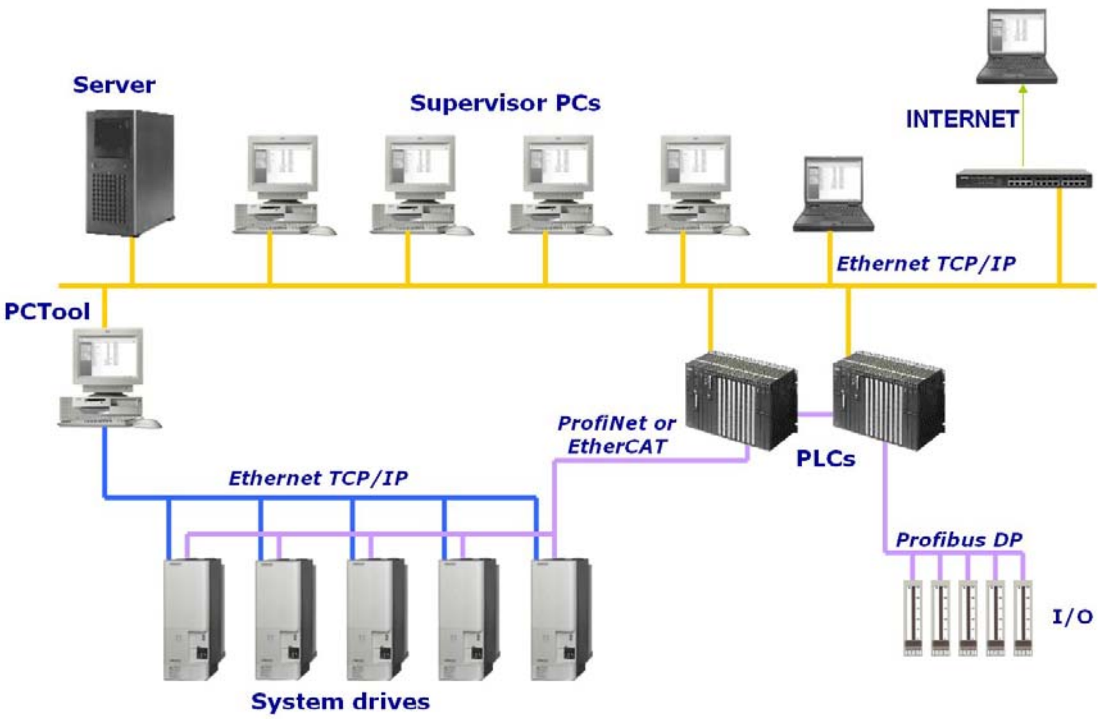

Figure 5 – Automation solution with commercial PLCs

A configuration such that indicated in Figure 5 can be used as instance in Rolling Mills for long products. This arrangement allows to maintain in the external PLCs the

functionalities to generate and supervise the references cascade while moving inside the drives those controls which requires a large amount of process data in critical time like minimum tension, loops, impact drop and adaptive control functions.
Using the Ansaldo Sistemi Industriali automation platform (ARTICS), the integration achieved is even more complete than with standard PLCs. The AMS (Ansaldo Micro System) main controller, typically based on VME or PCI multiprocessor racks, uses the same real-time operating system, programming environment IEC 61131-3 and tools of the *SYSTEM* platform. Therefore, the drives can be seen and used in the same way.
Such architecture, normally used in rolling mills for flat and long products, allows production of software for Automation Controllers (AMS) and drives (*SYSTEM*) using the same development environment (ARTICS Development Tool).

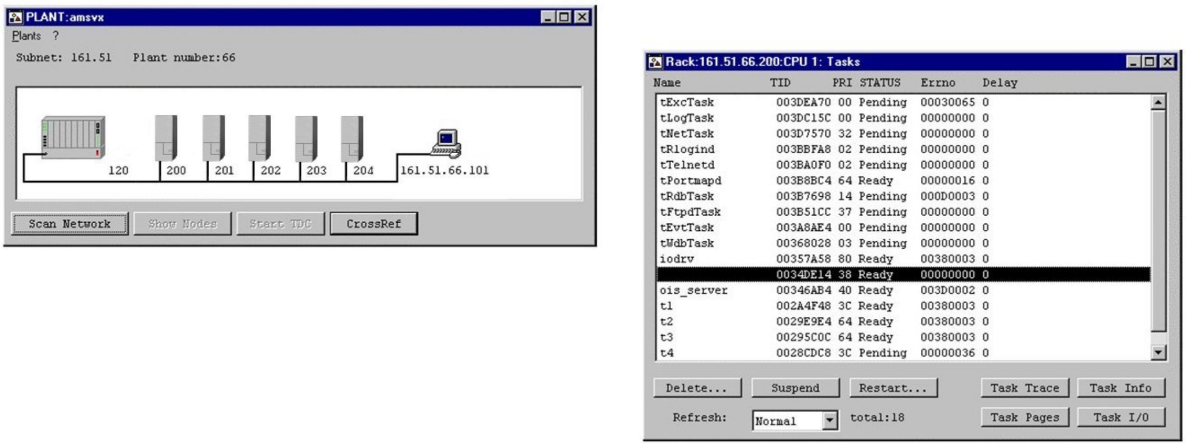

Figure 6 – Visibility of drives inside ADT (ARTICS Development Tool)

The first realization of the platform has been carried out in June 2007: it is a project activated in order to test the drive in standard conditions, with an external PLC connected in Profibus, and, in a second phase, to implement those same PLC sequences for layers lifting and bundles movements in the evacuation zone directly on-board.
Until now the *SYSTEM* drive has been used for some meaningful realizations like, for example, the flying shear control. This solution integrates on the same board both the AC drive control and all those control functions for cut and machine operation sequencing (see Figure 7).
The optimized PLC functions implemented for this application were added to the system libraries; by properly setting some dedicated parameters the user can enable and configure the shear control. All the commands can be sent to the system through the drive operator interface and the fieldbus.

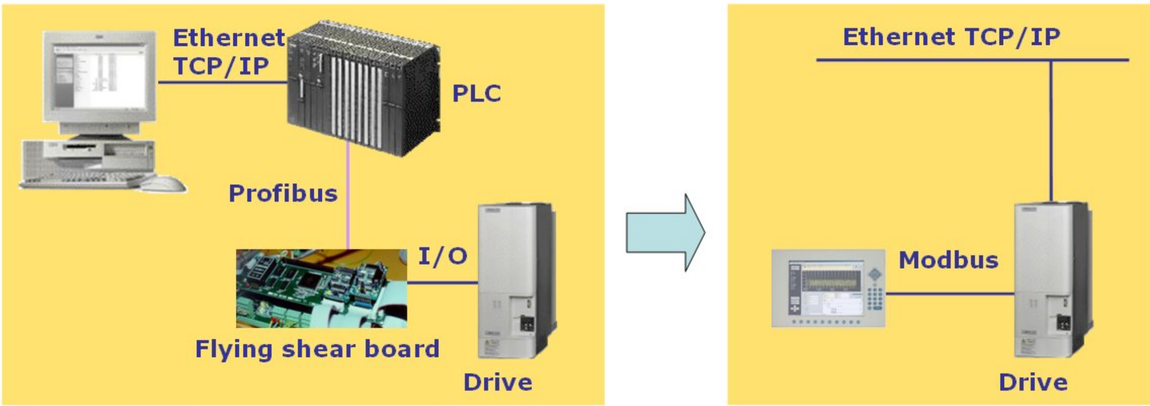

Figure 7 – Architecture of stand-alone flying shear solution

Complex functions such as Start stop shears, Clutch and brake shears, Chopping shears, Diverters, Laying heads and Carriages need an adequate interface with field sensors (encoders, position sensors, photocells for material presence..) and this is provided by dedicated interface card, which has the following principal characteristics:

1. 4 encoder interfaces
2. 16 digital inputs
3. 16 digital outputs
4. SPI Interface with *SYSTEM* card (through RJ45 connector or optic fibers)

All regulation functions are performed in *SYSTEM* card; the main loop principle of regulation (updating of counters, generation of theoretical speed reference of blades, auxiliary functions of I/O) is performed on interrupt each 400 µs.
The remaining functions (management of communications, calibrations updating…) are performed with a slower pace. The system operation consists of the generation of a torque and speed reference to the shear motor, suitable to be directly managed by the drive.
The essential inputs for the operation are:
- line bi-directional encoders
- sensor(s) of material presence placed upstream the shear
- sensor of blades in cutting position

The line encoder mounted on the machine defines the speed of the material arriving to the shear. There are 2 encoder inputs (selectable by the automation) because in case of shears placed at the inlet of the plate, in sequence we use the encoder of the finishing cage and that of the dragging associated to the shear. For any encoder input there is a control of channels and an adaptation that takes into consideration all the elements that contribute to define the ratio impulses/meter.
The line encoders supply the double information of speed (frequency) and space run (n° impulses).
It is possible to activate the line simulation, and collect the information of speed and space run not more by the encoders but from a frequency generated internally.
The impulses are counted in real time within the card, to build the two tracing counters in case there is the simultaneous presence of two bars: the first one detects the head position of the first bar (the one which precedes) and the second is associated to the head of the eventual second bar.

On the uprising front of the sensor for material presence, upstream the shear it is activated the head tracking; on the descent front it is stored in memory the position of the tail.

Then the head cut and the following cuts by measure shall all be managed with the same logic connected to the position of bar 1, while for the tail cut we shall use the information related to the position of the tail.

The blades start to move with a sufficient advance to accelerate, synchronize with the speed of the material to be cut and perform the cut in the desired point; then they stop in the standby position.

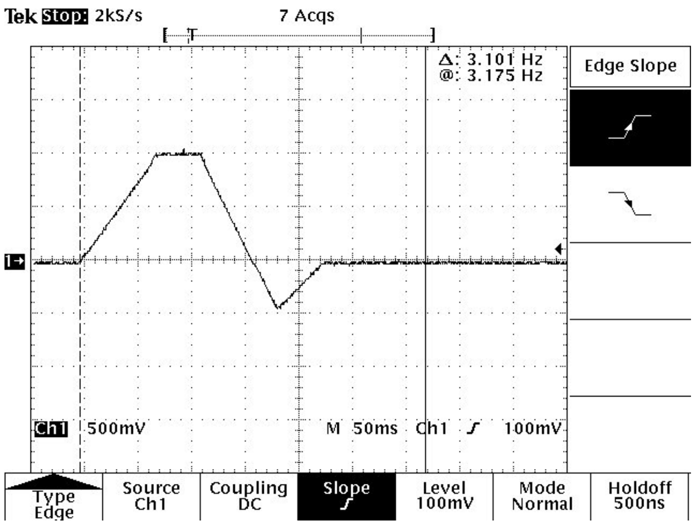

Figure 8 – Cut sequence and re-positioning of blades

Due to the facts there are different phases of control in the blades movement, which may partially be superposed, the card always operates observing the following priorities:

1. synchronous zone
2. cutting loop
3. positioning ring and time ramp

A set of auxiliary functions have also been provided, such as:

- Real speeds and diameters calculations
- Automatic slope change of acceleration / deceleration ramps
- Scrapping command
- Unload command
- Immediate cut command
- Test cut command
- Cut sensor check
- Cut error calculation
- Iron in progress calculation
- Line / auxiliary encoder speed calculation
- Pre-signal to cut output
- Simulation of line and auxiliary encoder
- Overspeed management

CONCLUSIONS

Microprocessor-based distributed control systems have big advantages when compared to centralized control structures.

Better performances

Assuming that process data can be exchanged in real time through a powerful communication link, such as ProfiNet IRT or EtherCAT, a complete and distributed control of the whole production line can be obtained with cycle-times under the millisecond (faster for EtherCAT).

Time consuming tasks and signal processing can be realized locally, using well-tested function blocks such as Minimum Tension Control, Loop Control and Impact Drop Compensation. Any customization can be realized directly by the user through the on-board PLC, increasing flexibility and portability of the system.

In Rolling Mills a good control of the process increases the plant efficiency, avoids cobbles and parts wearing and improves the final product quality. Not only a good measurement of the process quantities but also an appropriate signal processing and synchronization of the control algorithms are necessary.

Simpler interventions

To simplify configuration and use of the system, an abstract model of the automation plant can be realized. To each step defined in the model, the user can associate and configure a particular object of the production line (for example a stand) with its active regulators (for example loop control and impact drop compensator) and the connected machine (power unit control with motor).

Applying the concept of "parental relationship" to each step, a modification of the plant, such as introducing a new stand or a new section line, can be implemented just re-defining the "father-son-brother" relations without further interventions on the software.

Reduced costs

Communication systems play a leading role in distributed systems because they allow the continuous exchange of information between the automation components, keeping the physical separation that different levels and devices require.

The new System drive has the possibility to manage various communication interfaces at the same time and to integrate different typologies in the same unit. This new platform doesn't demand each user totally conform to regional and/or corporate standards. There can be both slave (for an higher network integration) and master (for remote I/O connection) interfaces, permitting to reduce the complexity and the cost of wiring and giving the openness necessary to work with pre-existent communication architectures, such as for example in partial revamping of Rolling Mills.

In addition, the approach of distributed control reduces the required performance of central PLCs, allowing cheaper and less complex solutions.

As a process automation specialist, Ansaldo Sistemi Industriali strives to deliver innovative technology and to develop market-leading power electronics solutions to meet the evolving demands of the industrial global marketplace.

The versatility and performance of the new S*YSTEM* low-voltage AC and DC Drive Platform will provide a better answer to the customer needs.