BASIC CONCEPTS OF REAL-TIME SIMULATION (RTS)

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Simularea modului de funcționare a sistemelor sau subsistemelor reprezintă un aspect important în studiul acestora. Obținerea unor modele matematice cât mai apropiate de fenomenele fizice ce se doresc reproduse sau îmbunătățite ne ajută în luarea deciziilor privind modul de optimizare a acestora. Conceptul de simulare în timp real a sistemelor permite existența simultană atât a unei părți de model matematic cât şi a unei părți fizice, obținându-se astfel o micşorare a gradului de imprecizie dat de lipsa anumitor fenomene, neluate în calcul în modelul matematic.

Simulating the operating regime of the systems or subsystems represents an important step in design process. Obtaining some mathematical models, as close as possible to the physical phenomena, that are to be reproduced or improved, helps in making decisions regarding the way of optimizing them. The concept of real time simulation of the systems allows the simultaneous existence of both a mathematical model part and a physical part, obtaining thus increase of the accuracy degree given by the poor knowledge of certain phenomena, not taken into consideration in the mathematical model.

Keywords: real-time simulation, fluid power systems, virtual instrumentation, remote digital control systems, web interface, data acquisition systems, process control solutions.

1. Real time systems

Real time simulation of the systems is very well applied in the area of complex applications, where some phenomena are still not theoretically well grounded or where the degree of complexity of the mathematical models is very high. Benefiting from the means of process identification and the power of

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computers, researchers can shorten the application development period in several domains, by generating a solution that is close enough to reality starting from the design phase.

Introducing computers in supervising and leading processes determinates the change of the technological systems. The high degree of flexibility they offer allows the "software optimization" of the systems. In this context, the opportunity of using hybrid simulators is highlighted, one part mathematical models and another part – physical system. This concept appears in technical literature as "hardware in the loop - HIL".

1.2. Using Industrial Computers in order to Control Automatic Processes Adjustment Systems

The thorough knowledge of the hardware components specific to the real time systems leads to the efficient use of soft and hard resources. Although as far as programming is concerned, they prefer developing programs without going to details regarding the machine they run on, in the field of real time systems this cannot be achieved.

1.3. Real Time Simulation of the Automatic Adjustment Systems

Currently, it is hard to imagine the analysis of a complex dynamic system without benefiting from the possibility to shape/simulate that system. Shaping and simulating dynamic systems are highly used techniques in the computer assisted analysis of the systems, representing at the same time an important step in the process of calculus system assisted conception.

The numerical simulation of the dynamic systems represents the process that leads to obtaining, with the help of the numeric calculator, information regarding the behavior in time of the systems' characteristic sizes.

Real time simulation of the systems represents the capacity of some calculus systems to perform numerical simulation in very short time intervals.

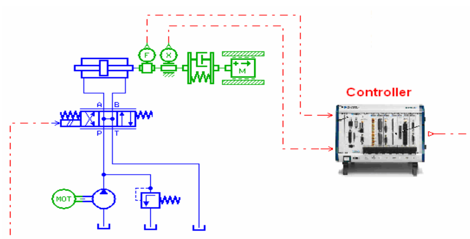

Fig.1. Real time simulation of an electro-hydraulic adjustment system

Real time simulation of the automatic adjustment systems usually implies simulating the command mode in order to test its functionality and performances. Also, it is a way to identify the possible situation when some malfunctions may occur. Another important aspect of the RT simulations is the possibility to simulate the subsystems. Thus, one may create hybrid simulation networks that include real subsystems and real time simulated subsystems.

Figure 1 shows a RT simulation application of an electro-hydraulic process. In this application, the operation system, electro-hydraulic component, was mathematically adjusted in real time with an advanced simulation language, and as part of the command the industrial controller was used. This means of adjustment/simulation of the system allowed both online tuning of the regulator, without using the due subsystem, and easy change of the electro-hydraulic subsystem features, in order to optimize it.

2. Modern architectures of the real time process simulation systems

In order to develop real time simulation applications, one may choose the necessary hardware and software components out of a large range offered by specialized companies. Among these offers, we may highlight the IPG-Automotive, PXI National-Instruments and Adwin systems.

2.1. IPG_Automotice systems

IPG_Automotice offers a series of services and equipments for hardware in the loop simulations, especially for the automotive area. With the help of the real time simulation systems they offer, one may proceed to complex simulations regarding the dynamic behavior of automobiles, motorcycles and trucks. IPG-Automotive offers solutions for performing analyzed systems simulations, performing tests as well as technical support. For RT simulations, IPG-Automotive recommends the “CarMaker/HIL” component. This helps to perform both simulation typical to the automobile components and simulation of electronic control units systems (ECU)

2.2. NI-PXI controllers

PXI (extension PCI for tools) defines a robust calculus platform for the measurement and automation applications. The PXI modular tools benefits from the advantages of the PCI (Peripheral Component Interconnect) high speed thoroughfare, which represents the de facto standard that leads the PC design, both hardware and software. Consequently, the PXI users can benefit from all the PCI advantages within an architecture that adds mechanical, electrical and software features, suitable for measurement applications, data acquisition and industrial automation. Entirely based on an open industrial standard, the PXI modular instrumentation represent an efficient solution, as it combines the high speed electrical architecture of the PCI with an industrial high reliable case, synchronizing functions, incorporated temporization and full inter-use with Compact PCI. The reduced size of the PXI system is ideal for a large variety of portable desk or rack applications for testing, measuring, data collection and industrial automation.

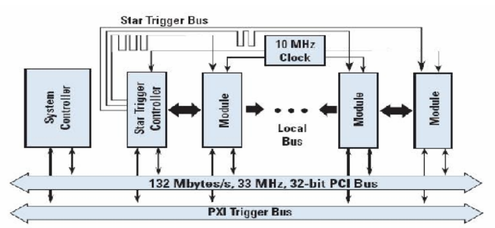

Fig. 2. The PXI Systems Thoroughfares – these systems allow the use of the PCI thoroughfare together with the local synchronizing and release systems

The PXI Real Time Controllers

The real time option of the well known LabVIEW graphic development environment expands its possibilities of creating real time incorporated systems that use smart measurement tools form the National Instruments. These include the inserting acquisition boards with own microprocessor, the PXI controllers and the FieldPoint network modules family.

The PXI controllers of the Real-Time series are different form the usual ones, because they have a hard drive with Run Time LabVIEW engine, running thus, instead of Windows, a real time operating system. The Real-Time controllers may run along with Windows, the two environments having the possibility to communicate.

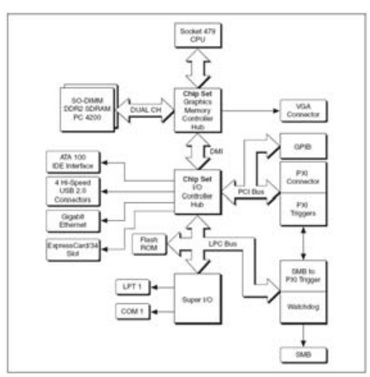

Fig 3: The block diagram of the NI PXI-8195/8196 system

2.3. Adwin systems

The Adwin systems are process controllers designed for data acquisition and fast automation applications. The applications developed by means of the ADwin systems are real time executed. The values of the acquisitioned signals and the events measured by these applications can be processed in certain periods of time. The ADwin systems have analogical and digital input/output (I/O) modules, a local processor, SHARC RISC or DSP and local memory.

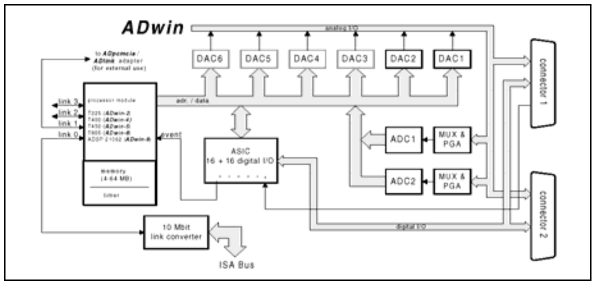

Fig.4 The ADwin Systems Architecture

All the ADwin equipments have a local processing unit and memory. An ADwin equipment has one of the three 32 bits RISC processors that are compatible with the cards. The specialized processing unit ensures the calculus and processing power for the high speed real time applications. As powerful the equipment is due to its architecture, the easy to program it is. The software used in programming this equipment is ADbasic.

3. The real time simulation of the electro-hydraulic adjustment systems

The electro-hydraulic adjustment systems are complex systems, where there occur both phenomena associated with the liquid flow in the field of volume hydraulic transmission and phenomena specific to the automatic adjustment processes. Due to the complexity of these phenomena, the establishment of optimum solutions for designing and producing them is done frequentative. Satisfying the performances imposed implies the use of mathematical modeling and numerical simulation processes. In the field of electro-hydraulic adjustment systems, the hardware loop simulations allow verifying and tuning the command algorithms in real time.

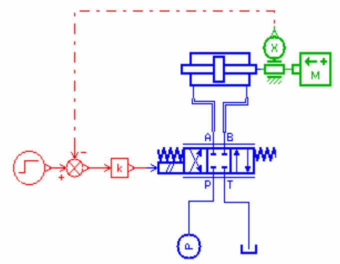

Fig. 5. Electro hydraulic position control system

Closed loop transfer function (s) :

$$H_0(s) = \frac{z(s)}{y(s)} = \frac{K_v \omega_h^2}{s^3 + 2\zeta\omega_h^2 s^2 + \omega_h^2 s + K_v \omega_h^2} \qquad (1)$$

Equivalent closed loop transfer function (z):

$$H(z) = Z[H_{EOZ}(s)H(s)] = \qquad (2)$$

$$= Z\left[\left(1 - e^{-st}\right)\frac{H(s)}{s}\right] = \frac{z-1}{z} Z\left[\frac{H(s)}{s}\right]$$

3.1. Real Time Simulation of the Non-Linear Model

In order to create and test real time applications, one may use two hardware systems that run in parallel or a single machine with a real time operation system (RTOS). In the first case, they usually use a PC connected to a digital signal processor industrial machine. (DSP). Due to the increase of the calculus power of the PC systems, they may represent a competitive enough support in order to test a very high number of algorithms of guidance and real time processes.

The operation systems that run on “real time machines” must obviously be “real time”. For the dedicated platforms, there usually are OS-RT systems developed by the producer companies of the equipments. The OSs of this type must be able to:

- execute several tasks apparently at the same time (multitasking)
- prioritize the execution threads
- benefit from a sufficiently large interruption levels

In order to real time simulate the electro-hydraulic servomechanism, they used the real time development environment for Windows in Matlab, that is the real time Windows Target toolbox.

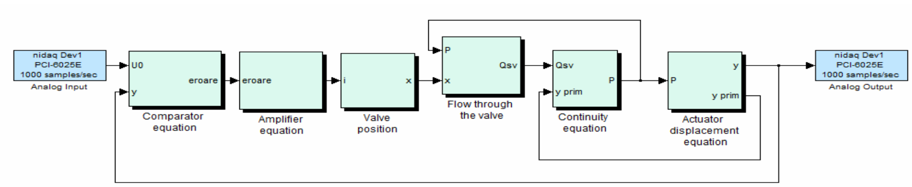

Fig. 6. Real-time simulation of electro hydraulic position control system

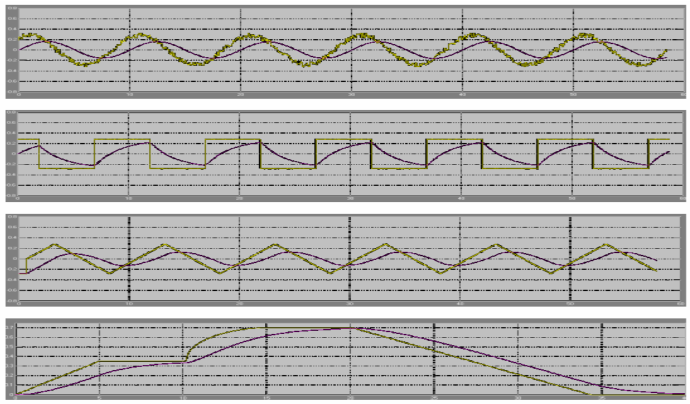

Fig. 7. System response in time for different excitations signals.

3.2. Real Time Extensions for Windows

Because the OS of the windows family are not natively real time, a series of RT extensions were developed for them. Among these, we may mention: the real time *rtwin* kernel in Matlab, Ardence RTX, RTX(VenturCom). These extensions provide the Windows NT (New Technology) OSs real time operating features. Real Time Windows Target allows the real time use of simulation networks developed in the Simulink graphic programming environment. For the connectivity with the real environment, this toolbox contains a series of drivers for the acquisition and data processing tools. Therefore, one may use a large range of AD/DA systems from different producers, such as: Advantech, Analog Devices, Axiom, ComputerBoards, Data Translation, Humusoft etc.

The advantage of using this product is given by the possibility to quickly develop hardware in the loop simulators, to control processes, to simulate components of the processes or even whole processes, benefiting from the Simulink powerful mathematical apparatus. This toolbox uses a very small kernel in order to run RT application in a very short time interval.

Fig. 8. Simulink to .exe application model diagram

The simulated model of the system was implemented by means of the xPC- Target toolbox in MATLAB. This component of the mathematical calculus language allows transforming an Intel compatible PC work station in a real time machine similar to the dedicated platforms, like dSPACE or xPC Target-Box.

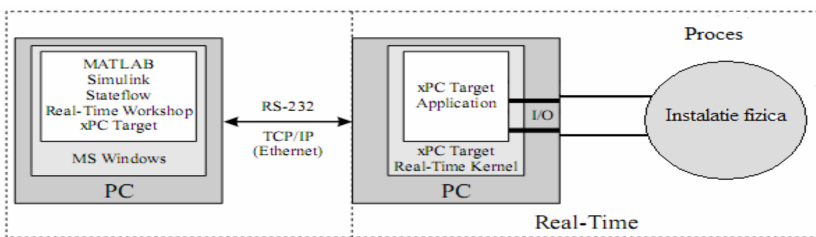

Fig. 9. xPC Target system architecture

The real time interface (RTI) in Matlab allows connecting the Simulink model and the Real-Time Workshop (RTW) in Matlab to the harware station (PC, dSPACE, etc) able to execute real time simulations. The RTI interface automatically converts the mathematical model of the Simulink system in source C code, generating also the executable file of the application.

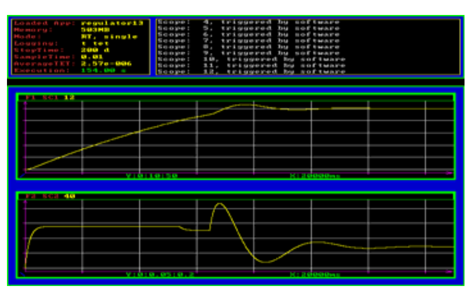

Fig. 10. xPC Target display interface

In order to test several leading algorithms, one may use the experiments drawing in above. In this situation, the system is comprised of the RT mathematical model of the system and the physical regulator (industrial computer). This option offers the advantage of simplicity in performing the experimental assembling and the possibility to use the physical system without any other subsystem.

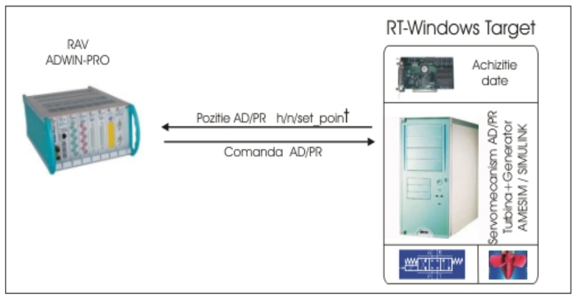

Fig. 11. Software real time simulation
(mathematical model + ADWIN-PRO process computers)

The use of the xPC Target toolbox allows generating a monitoring and online control page, viewable over the internet. With this page, one may view and modify the model's parameters, the work variables, stop and restart the simulation process, design charts regarding parameters. Although all these tasks obviously use the systems resources, they do not affect negatively the evolution of the simulation, as they are automatically run with a certain execution level. All the necessary actions for generating the website and the charts are done only after the RT processes execution.

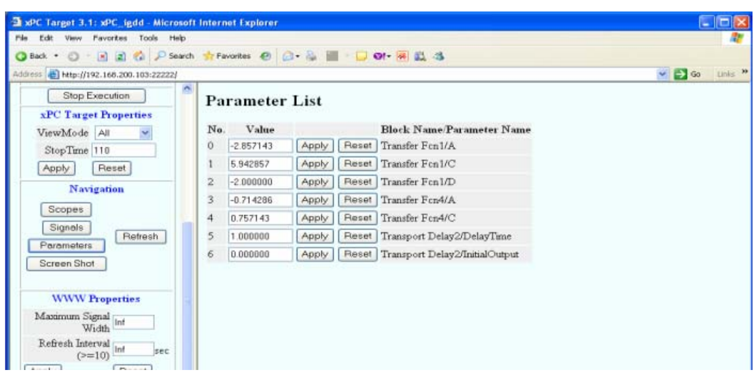

Fig. 12. Web interface of xPC Target application

4. Conclusions

Real time simulation of the analyzed system presents obvious advantages. One may test, with a low level of risk, different ways of adjustment and control. Although tuning on site is inevitable, the real time analysis process allows the decrease of the time necessary for tests and tuning in the real process. The decrease of time necessary for achieving these objectives leads to minimizing costs and, at the same time, decreasing the possibility of physical damage of test equipment.

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