Use of IEC1131 programming in virtual laboratory

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Abstract **— Virtual Laboratories are using in automation design inside of Integrator Systems. If the use of IEC 61131-3 languages is standardised in the industrial automation programming, why not to introduce these languages in the develop of Virtual Laboratories?. Virtual Laboratory of Automation in University of Oriente (Cuba) works to this purpose. SDAI teaching system include model analysis and design in PN, programming and simulate control system in LD and SFC languages and finish with verify functional requirements in real installation. The integrate work of all parts is achieved for the use of IEC 1131 graphical languages facilities.**

KeyWords: Programming languages, Programmable logic controllers (PLCs), Process Control, Virtual laboratory

1. INTRODUCTION

The industrial automation is one of the technological branches that more quickly change with the modern scientific-technician development. The use of Computer science and communications new technologies in the Automation has achieved extraordinary qualities in their application and teaching. One of these advances is the use of Virtual Laboratories by means of Intranet and/or Internet [1].

For Virtual Laboratories we understand those systems developed on PCs that allow the design, programming and simulation of automated systems (process, control system and their HMI), but that they can be used interactively by several users in a local net of computers (Intranet) and even through Internet.

For many years is recognised impossible the efficient automation design without to use of future automated systems simulation [2]. For that reason, the use of Virtual Laboratories has spread broadly so much in automation companies, universities and technological institutes of the branch, that which has given a more complete dimension to this design necessity [1]. Also create the conditions for the development of Integrator Systems in the automated design.

An example of development of these systems in international level are the multiple works developed on LabView of National Instruments for teaching in several universities. One example is the educational system developed by professors of Swiss Federal Institute of Technology in Lausanne (Swiss) [1]

Polytechnic University of Catalunya (Barcelona, Spain) and University of Oriente (Santiago de Cuba, Cuba) are working together to create a Teaching System of Industrial Automation (SDAI). This system includes virtual and real laboratory systems to use in design, programming and simulation of automated systems for practical class in both universities.

Using several package of software to help automation teaching like LabView, ISaGRAF, Visual Object Net, MatLab, and PLCs programming software, we organise our educational system. It include a design part first, in second, use a programming part, after as, they realise a simulate probe, and finally, application program is verify in real installation. This paper has the same ordering.

II. DESIGN SYSTEM OF SDAI

International scientific and academic community are work finding formal methods to modeling and design automatic systems to allow high quality in PLCs automation networks [3, 4, 5, 6, 7, 8, 9]. We use a general methodology to modeling, verifying, and validate PLCs automation designs with Visual Object Net 2.0 (Ilmenau University of Technology, Germany) and MatLab 5.3 (MathWorks). It has a purpose to teach automation designers to obtain evaluations of theirs designs using formal methods in Petri Nets (PN).

It includes the study of theoretical concepts about PN and methods to verify behavioural and structural properties [10] such as Liveness, Boundedness, S- and T- Invariants, and others, to conform a well application design in PN.

In Figure 1 are represented two hierarchical subnets of modeling a choice of control variant and the execution of one of then in a Laboratory practice. It use a Visual Object Net to design and simulate a PN model. The properties analysis is execute using programs in MatLab.

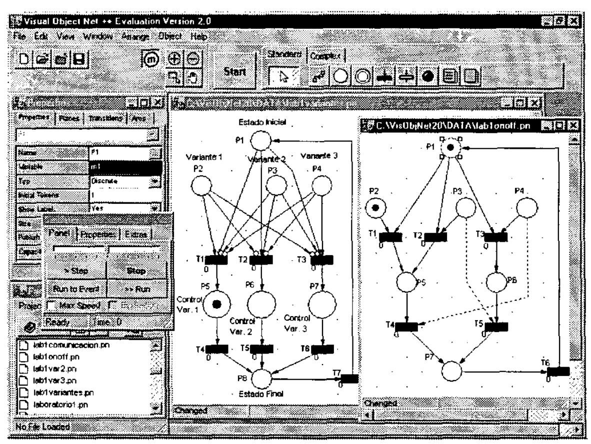

Fig 1 Two hierarchical subnets using Visual Object Net

Visual Object Net [Fig. 1] allow ease visual interactive environment to conform and simulate several PN models, from Place/Transition Nets to Continuos Nets.

The use of formal methods to analysis and design the applications with PN models allow that each subnet has the required Liveness and Boundeness, without deadlocks or forbidden states in discrete event system model. It permits an efficient verifying of model. After of these, model execution simulation permit final adjusts to validity of user requirement in the model.

III. USE OF IEC 61131-3 COMPATIBLE LANGUAGES IN VIRTUAL LABORATORIES AND REMOTE MANAGEMENT

A. Programming system in SDAI

After create an efficient design of automation system using formal methods we begin the second part of SDAI, the programming of this system.

Two technological lines exist to implement automated systems: the programmable logical controllers (PLCs) and the interface cards in computers (PCs) [2].

A market war exists among both lines to obtain supremacy in the use [11]. They develop new potentialities in one, which appears quickly in the other one.

Internationally strong defenders exist in both lines. For example, we have, in PLCs, the papers of CE American Journal, such as Morris Feb-98 [12]. In the use of PCs in industrial automation we can point out the papers of the number 299 Sep-99 in the AeI Spanish Journal [13]

There are two systems that simulate with big possibilities both lines, allowing the training of beginners and the design tests to the specialists. These are the ISaGRAF 3.2 (CJ International) for PLCs and the LabView (National Instruments) for the PCs.

ISaGRAF allows programming in 5 languages of PLCs standardized internationally by means of the IEC 61131-3: Its are Instructions Lists (IL), Ladder Diagram (LD), Functional Blocks Diagram (FBD), Structured Text (ST) and Sequential Functions Chart (SFC).

By means of a group of simulated digital and analog input/output modules, it allows in screen a graphic configuration of a virtual PLC that acts efficiently (small right window in Fig. 2). If it is adding with graphic and programming facilities for process and visualization devices simulation (principal window in Fig. 2), the complete simulation of any application is achieved.

Taking advantage of the partition standardized in the IEC 1131 for the creation of application programs of PLCs (Begin, Sequence, and End parts), it is possible to create, inside of the virtual PLC in ISaGRAF, the control program (Begin and Sequence parts) and the simulation of the process (End parts).

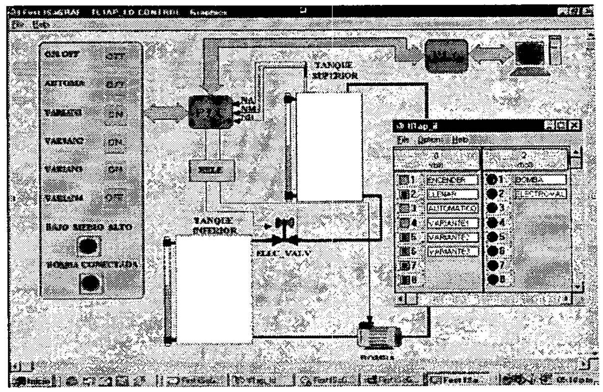

Fig 2 Virtual installation of two tanks using ISaGRAF

Using the association facilities of Boolean variable to icons and analog variables to graphics of bars (p.e. communicant vessels in Fig.2), the real behaviors of the automated systems are achieved to simulate in the screen of the PC. This effect gives high truthfulness to the system allowing the improvement of the design of the control for any specialist.

In the case of the control by means of PCs the graphic programming in G language by means of the connection of VI (Virtual Instruments of LabView), allows the graphic simulation in the screen of the PC of the control by means of interface cards of anyone process (see Fig. 3).

The facilities of the LabView guarantee that most of the components required in any application are inside the collection of objects of the system and those that not, can be created by means of graphic combinations of programming using the existent ones

The graphic programming in LD and SFC of the ISaGRAF and in G language of LabView allows to cover the simulation of the whole field of automation applications. This allows the quick programming training of beginners and the efficiency of the program design of automation professionals.

For all the above-mentioned we select these two systems to create our virtual laboratories of automation in programming part of SDAI system.

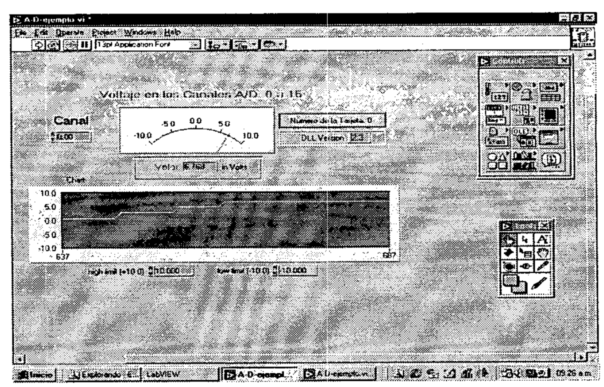

Fig. 3. Control Panel of analog signal 0.00 in ME300 using LabView

B. Facilities to translate model to program in graphic languages

The use of graphic languages in the programming of automation systems is broadly diffused in small and medium applications [14]. But the increase of potentialities of these languages also simplifies the programming in big and complex automation systems [15].

Exist high proximity of the graphic languages as the SFC and LD (IEC 61131-3) to the tools of modeling of discreet events systems, like the Petri Nets [7, 8, 9]. It allows professional designers to pass directly from the modeling one to the programming of the application and in many cases in an automated way.

The integration of Visual Object Net facilities, and the qualities of the IEC 1131 graphics languages inside the ISaGRAF with the wide facilities of G languages of LabView allow to create a complete system of Virtual Laboratories of Automation.

The easy model design using Visual Object Net create a well beginning of a good automation. These models are rapidly translated to graphical PLCs programming languages.

A station of training in design of PLCs programming you can create quickly on the ISaGRAF. But exchanging files of data between this system and the LabView can take advantage the wide multitask potentialities, work in local net and connection to Internet of this last system being able to organise this way a system with the qualities of a Virtual Laboratory of Automation.

If to this way, we add the communication among the real PLCs of the laboratory with the LabView we create the remote control facilities that allow the real verify of virtual design results.

C. Validate to real system in SDAI system

Among the Polytechnic University of Catalunya (UPC, Barcelona, Spain) and the University of Oriente (UO, Santiago de Cuba, Cuba) a very strong collaboration has settled down for the development of Virtual Laboratories of Automation. Especially the professors of the Electric Engineering Department of the UPC and of Center of Automation Research (CEA) of the UO have carried out several trips of specialists' exchange to perfecting their teaching and training tools for professional specialists and graduate degree in Automation.

This has allowed the technology, software and Know-how exchange about automation that has rebounded favourably in the quality of the specialized teaching and training in both universities.

This collaboration permits to create several installations to validate automation design in real world (Fig. 4). It permit students to complete theirs know-how of automation projects in Laboratory, because they need to consider implementation problems. Especially, the functional activities synchronisation by communications by local networks

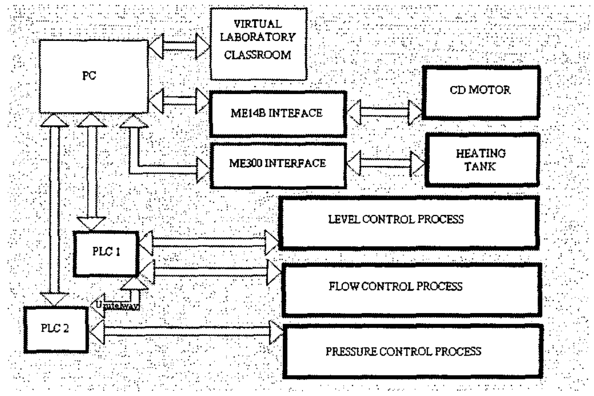

Fig. 4. Real installation of control system by Intranet in Virtual Laboratory classroom

In Control Process Laboratory at University of Oriente, we have five process management by two TSX17 PLCs and ME300 (or 14B) interface. These processes include fundamental process control variable like pressure, flow, level, temperature, and speed. Two PLCs are communicated by Unitelway network (Telemecanique). One of this PLCs can be programmed as network master including PC communication program. Intranet connects this PC with others PCs in Virtual Laboratory Classroom.

The local networks between PLCs have to be programmed using PL7-2 languages (Fig. 5). They are very similar to LD and SFC IEC1131 languages used in virtual version by ISaGRAF. The students have to program the communication between PLCs in theirs automation program. But one of them is master PLC and it includes PCs communication too. In Figure 5 is represented text block to communicate with PC in master PLC using PL7-2 languages.

But this communication needs the PC attention in the other side. For that reason, it has to program this attention in LabView (Fig. 6)

Besides, in real installation the students need to prepare a HMI interface between supervisory system and operators. One example of this are HMI level control developed by a student using LabView represented in Fig. 7.

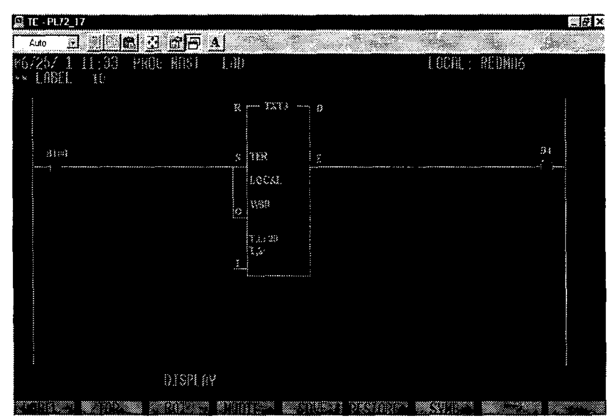

Fig. 5. Communication block with PC in PL7.2 language

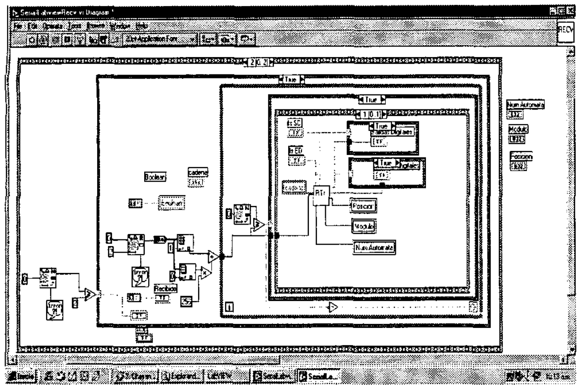

Fig. 6. Data Acquisition program in LabView

IV. EXPERIENCES IN USE OF SDAI SYSTEM

The experiences of use of virtual Laboratories with the ISaGRAF and the LabView have fourth teaching courses with excellent results in UO.

We have 32 simulated automated processes on both systems that embrace from applications of sequential control and electric management until process control including the intelligent control (Fuzzy and neuronal algorithms) and continue their amplification to adaptive algorithms and others.

In the UO we have trained in this facilities 193 new automation specialists and 120 professionals of the branch. These professionals are linked to the industries of the petroleum, cement, construction materials, electricity generation, nutritious and mining of the oriental area of Cuba, as well as of specialists that assist the automation hotels and intelligent buildings.

For that reason, the use advantages of this virtual laboratories on ISaGRAf and LabView for the automated systems design have been disseminated by the design and projection groups of automated systems of the territory.

In this course we adding the modeling part using Visual Object Net to teaching the use of formal methods of design to decrease errors in automation projects.

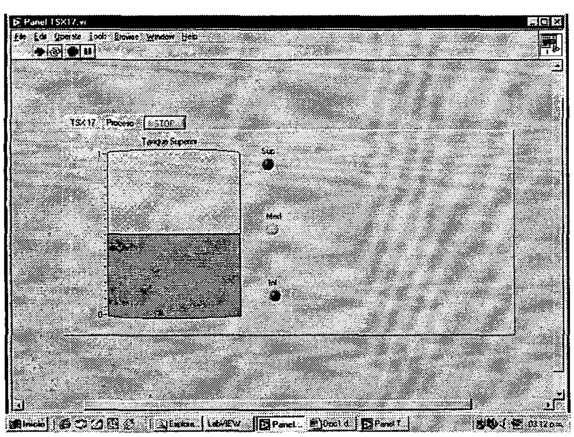

Fig. 7. HMI Panel developed by students in LabView

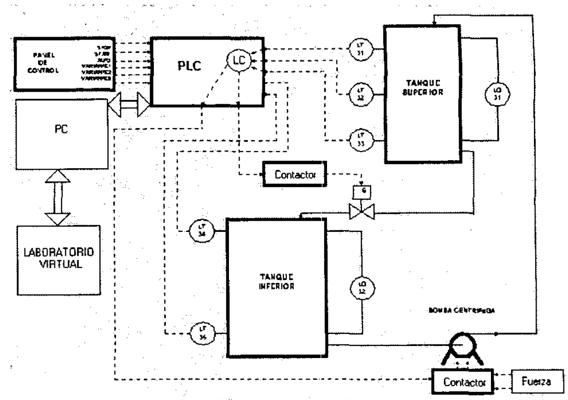

Fig 8. Real installation of two tanks to remote control in Virtual Laboratory

Besides, we are working with UPC professors to create Internet link with this system from Barcelona. It allow to utilise this SDAI systems by UPC students.

Inside the virtual and real facilities mounted in FIE (Electric Engineering Faculty) of the UO stay the pioneer installation in these works. It is dedicated to the control of the filled and casting of a two tanks system (Fig 8) and are represented in all phases by Fig. 1, 2, 5, 6 and 7.

The use of the graphic programming languages of PLCs registered in the IEC 61131-3 in the training of students and professionals of Automatic has allowed the design of different variants of sequential and process control of the installation.

The PNmodel analysis and design of control system (Fig.1), allow to configure good structured design of control algorithm. It use the high similarity between PN model with LD and SFC IEC 1131 languages, to help translate process.

After have control system program in IEC 1131 languages, the simulation of this installation by means of the ISaGRAF (Fig. 2) allows the users initially to carry out the adjustments required to its designs without affecting the real installation (Fig. 8). Then by means of the remote access the real operation of the optimised design is verified.

By means of use of Intranet in FIE (UO) it achieves the access from the computers classrooms to the virtual and real versions of this systems. The students train using different versions of control algorithms for the level in the superior tank using from the classic ON-OFF until two or three positions algorithms with hysterics and/or dead zone [15].

This way they are linked the facilities of the virtual Laboratories with the advantages of graphic programming languages of wide use in the industrial automation [12].

This installation in their virtual and real variants this now entering in the second stage of improvement of these virtual laboratories that is the remote control by means of Internet that allows their handling from the UPC. We will hope that stay in complete use via Internet in March 2002.

V. CONCLUSIONS

The development of the Virtual Laboratories has taken great peak at world level for the big interaction facilities that allow the new technologies of computer science and the communications. Inside this, the virtual laboratories dedicated to the training and teaching of Automatic guarantee the suitable interactive space for the development of this speciality.

For this reason the works that we develop in collaboration the Polytechnic University of Catalunya and the University of Oriente to achieve these purposes have had a very positive effect in the specialists that are related with these centers.

The mixture of the programming facilities with IEC 61131-3 compatible languages and the kindness of the virtual Laboratories guarantee the volume and rapidly of the training by means of the Intranet.

The use of graphical software in all phases of project (Visual Object Net in model analysis and design, quickly translate to LD and SFC, ISaGRAF and LabView in programming and simulate, and PL7-2 y LabView en real world) allow complete integration of SDAI system around IEC 1131 standard.

Now, we are enlarged the facilities of it, use in the Intranet to other classrooms specialised in Automatic and for the multiple access from Internet.

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