Process Flow Analysis for flexible, integrated automation

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ABSTRACT

Integrated Automation & Control shall rely on robust application architecture that allows:

- Safe operation,

- Flexibility to make the plant responsive to business requirement (production schedules, new products development) and to support the assess lifecycle

- Context aware, filtered and pertinent information attached to the product being processed as well as to the containing / processing equipment.

Batch processes have beneficed of ISA S88 standard that defines a robust framework to separate equipment control from process control in an object-oriented approach. This concept may be favourably applied to any process: It has been repeatedly suggested adapting the standard to extend its domain to continuous and discrete processes.

Fieldbus philosophy and distributed functions blocks go even further by allowing equipment entities to become independent servicing entities that can be linked and orchestrated for performing process tasks.

Process flow analysis was developed to address the safety concern of chemical multipurpose process cells. It makes ISA 88 concepts very practical and helps to address the architecture duties stated above.

This simple, pragmatic methodology has proven its ability to model plants in a way that guarantees the operation safety and preserves the inherent plant flexibility.

INTRODUCTION

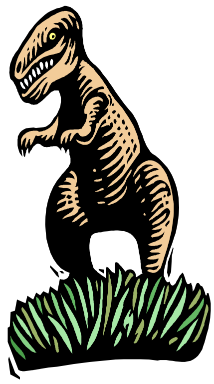
Automation is part of Humanity way of life for ages. Automation was first developed by humans to lighter their work. It is now more focused on efficiency and productivity improvement.

Nature itself uses automation extensively. Our body keeps its temperature at 37 °C unless a microbe attack requires a higher set point. It manages many muscles to control its vertical position.

However, Automation became a specific science recently, encompassing several old sciences and technologies such as watch making, fluid dynamics, electrics and electronics, hydraulics, physics…

As far as process control is concerned, it is interesting to remember that the first control systems were based on a fully “decentralized” approach: local pneumatic controllers were located directly near the valve or the sensor (don’t you remind some level controllers able to directly control a valve by their embedded controller? This is exactly what Fieldbuses promise us.).

The powerful TyRex Model

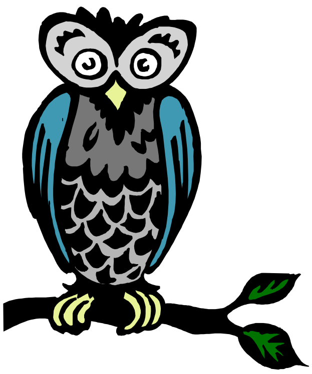


The early ages of modern automation, using computer technology, looked like this disappeared animal: A big head for a heavy brain taking care about all foreseeable or unexpected events to keep the machine running.

That works well for slow changing environment and fixed configuration: dinosaur’s lasted millions of years, humans are basically designed on this model.

Old DCS systems were able to manage entire refineries in a stable, efficient way.

The stupid Bird model



Everyone believes that birds have limited intelligence: their brain is so small that they seem to be only able to cheep and eat and… However, they are able to take advantage of any air movement to stay flying in the sky with minimized energy consumption.

Come back to humans: have you ever seen a virtuoso playing piano? A secretary typing on a keyboard? Engineers have certainly a heavier brain than girls who translate their complex reports from handwritten copies to clean typed sheets. (Many apologize for this sexist allusion!)

Where is this intelligence located? In muscles driving feathers or fingers! Such performances would be unattainable if based on communication flows from sensors to actuators through a central controller, even with a big controller or brain (which would be so heavy that the bird would never fly – What about the pretty secretary?).

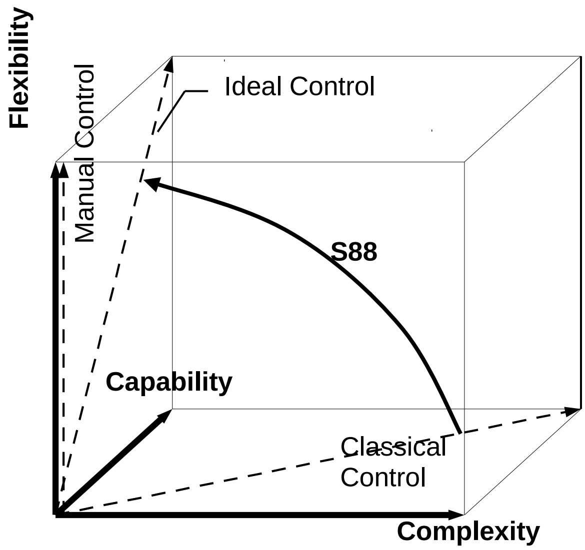
By locating small pieces of brain at the right location, implementing simple, basic mechanisms at the root of each feather, the bird is able to optimally manage all its body whatever happens in the sky. Its decision taking cycle is extremely short and basically fully adapted to the intended overall operation.

More than computation and information flows capacity limitations, the new constraints of modern industry impose the second model. Our modern, “Integrated Control Systems” would better behave like carefree birds rather than massive, murky Tyrannosauruses.

This model is more complex to implement, however. New control implementation ways are being paved as Process Flow Analysis.

ISA 88 STANDARD FOR BATCH AND NON-BATCH AUTOMATION

Lets look at the following figure from D. Flemming and V. Pillai. *Flexibility* deals with changes within all production system lifecycle: scheduling constraints, process specifications, and equipment modifications. *Capability* is what functionalities can be automatically performed. *Complexity* is the overall effort needed to meet the automation requirements.



The diagram shows that classical control complexity grows with capability. It also presumes that it does not deal with flexibility.

It is also assumed that everything can be done manually in term of flexibility; however, most of the real situations will not be addressed in manual, leading to a poorly capable system.

S88 is intended to simplify the control, addressing flexibility and capability concern at the same time.

Figure 1

The ISA S88 standard was built to help batch automation design. It relies on few simple principles:

- Separate the physical model and the procedural model
- Separate the process control and the Equipment control
- Define object models that allows extension and collapsing

This is all but specific to Batch control: any process can be addressed by the above concepts. A continuous process is simply a batch process with a very long “production phase”. The important thing is the dual approach for Equipment Control and Process Control.

The following figure shows how the S88 models fit within the 3 lifecycles of any process cell:

- The Product Engineering
- Equipment Engineering
- Production Schedule

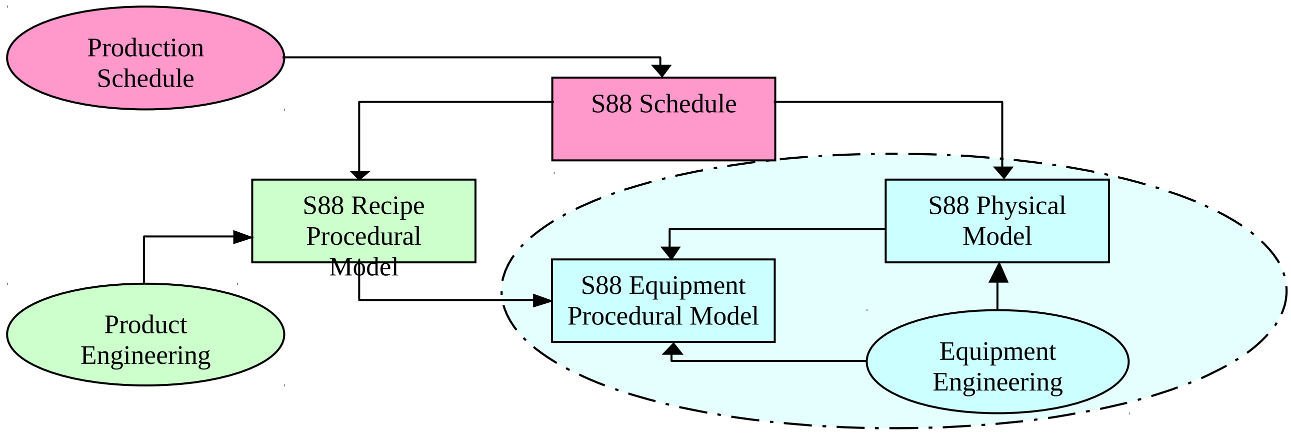


Figure 2

The automation effort corresponding to these three lifecycles must be addressed in an independent manner in order to comply with their inherent asynchronous characteristics.

The Flow Analysis method focuses on the Equipment part of the S88 domain, helping to define Physical and Equipment Procedural (Functional) Model.

If we now consider the operational scheduling, the control system structure should look like this:

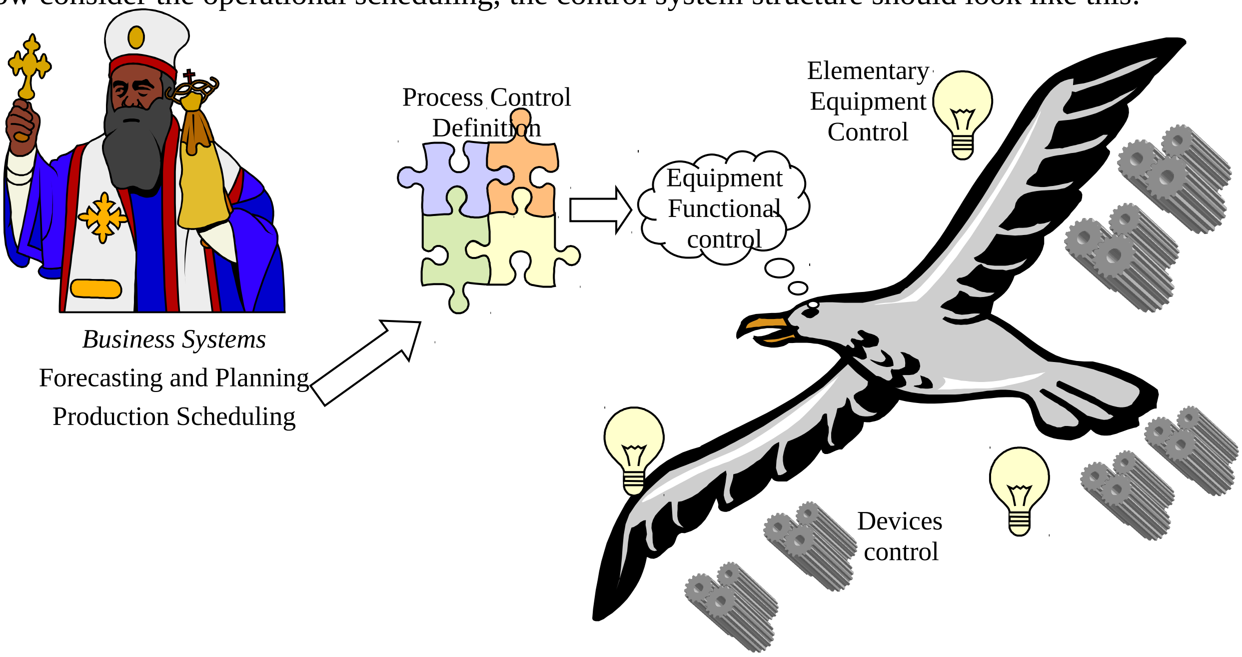


Figure 3

We can translate that allegoric image into the intended control system architecture:

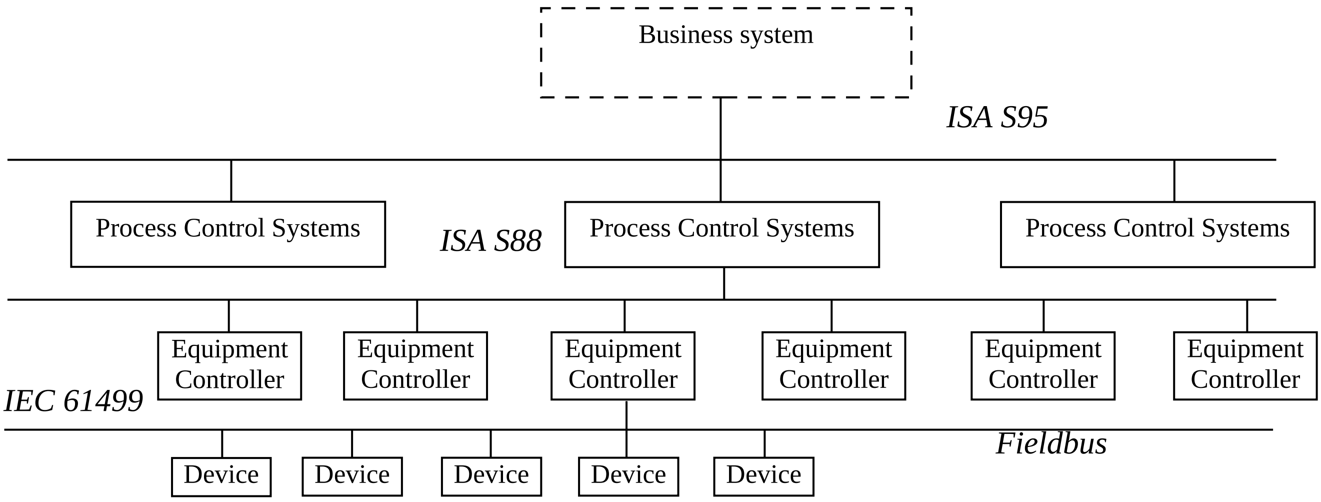


Figure 4

This structure becomes familiar, and standards already exist or are under development:

- ISA S95 for Business Systems – Control Systems integration
- ISA S88 for Process Control / Equipment control decoupling
- IEC 61499 for dispatched functional execution
- Fieldbus standards for “intelligent”, standardized devices

How this multi-tier architecture may work in practice? Without a robust method, it will be difficult to implement and maintain such a control system, dealing with commands and faults propagation, control modes, exception handling, heterogeneous origin of components...

Here comes into play the Flow Analysis methodology.

ORIGIN OF THE FLOW ANALYSIS METHOD

In 1988, Rhone Poulenc, a French Chemical Giant tried to find out a method to secure the operation of its critical chemical and pharmaceutical plants, whatever is the level of automation. It focused on the most sensible multipurpose batch process cells. How to define a robust control where the safety and the control integrity are not affected by exceptional manual operation or interlocks? The next figure shows how several decision actors may control a particular actuator:

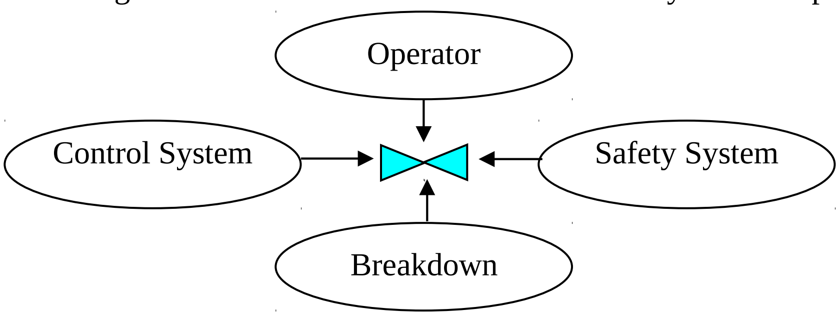


Figure 5

This is why automation is a complex job: what to do if the operator takes control of an actuator that should be handled by the control system at a particular time? Is it safe to open this valve in the actual conditions? What to do if the actuator goes wrong?

In 1986, Jean-Michel Rayon and Michel Favier began to define a methodology that distinguishes Equipment and Functional objects.

They bring together in 1989 to develop the first real project. Rhone Poulenc named the method “ASTRID”. Jean Michel Rayon developed authoring tools and execution engines to support the method and called it “DELTA NODES”.

The SP88 committee started about simultaneously on similar roots. However, it stayed at a higher conceptual level, being more focused on product processing than equipment control.

The method definitely focuses on Equipment Control. It continuously evolved by adopting S88 terminology and adding successively physico-chemical status control, product tracking, “Padlock” concept, limited resource control…

BASICS OF FLOW ANALYSIS

The Flow Analysis “explodes” a Process Cell into elementary pieces of equipment that can be linked together to produce “Flows”.

All other aspects of the method follow from that definition. The next figure illustrates the modeling technique:

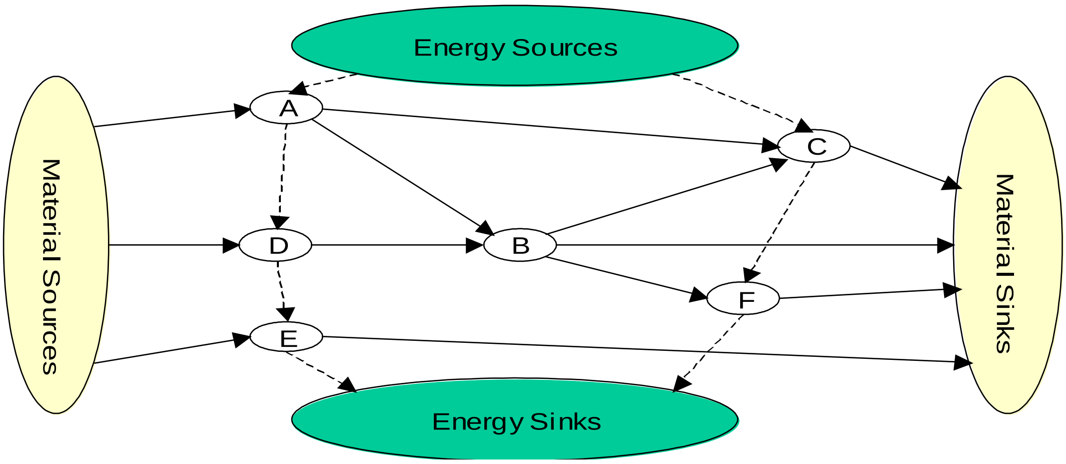


Figure 6

- ⇨ **Inputs and Outputs**: Material and Energy "Sources" and "Sinks"
- ⇨ **Containers**: Transformation Nodes (machines, pumps, vessels, reactors, exchangers) and Transfer Elements (material flow lines, conveyors, energy streams…)
- ⇨ **Contents**: *Path* (static) or Material Flows (dynamic)

Containers are grouped into **Resources** as elementary equipment entities, providing the lowest physical model layer known by the control system. Resource boundaries are logically defined as closed section created by isolating actuators.

By assembling resources together, ‘flows’ can be established and the corresponding functionalities defined. The resource allocation is dynamic and exclusive.

At any time, the product inside the processing equipment is strictly located within a particular set of resources:

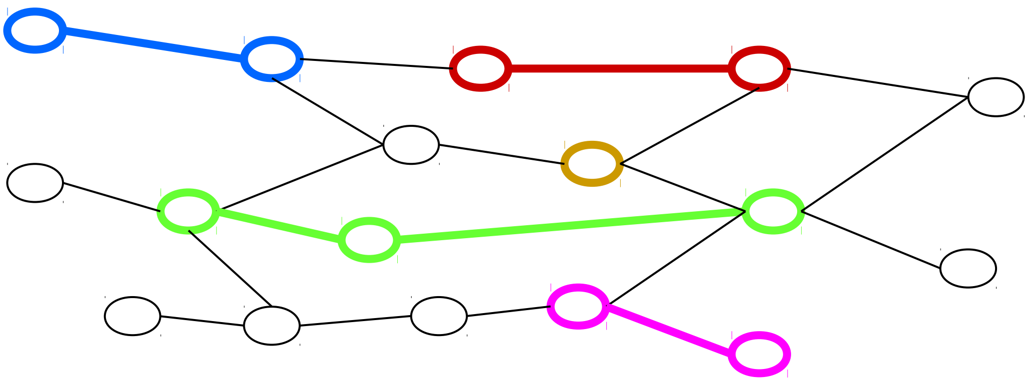


Figure 7

OBJECTS COLLABORATION

The method takes care about 3 objects categories:

- Devices: Sensors and actuators and their associated behavior
- Resources: Physical entities and their associated data and behavior
- Functions: Services that the process cell can provide by using one or several resources

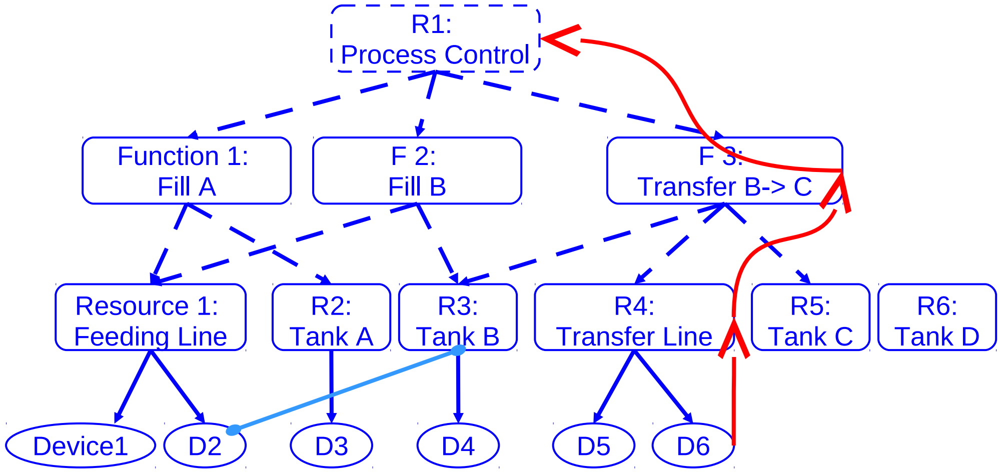


Figure 8

- Devices are tightly attached to Resources
- Resources are dynamically linked to Functions.
- Commands propagate top-down:
  - o Process control request Function to operate using specific parameters
  - o Functions request Resources to execute basic strategies
  - o Resources activate actuators
- Faults propagate bottom-up:
  - o Device fault leads to Resource fault (blocking or non-blocking)
  - o Resource fault leads to Function fault
  - o Function fault leads to Process control fault

If an isolating actuator (at the boundary of 2 Resources) goes into fault, both adjacent Resources go into fault.

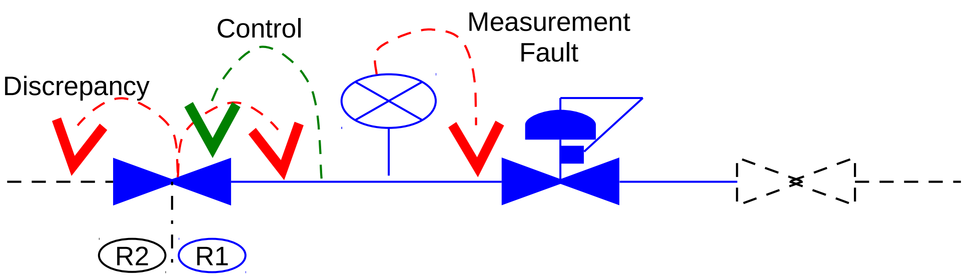


Figure 9

An appropriate settings of fault blocking / non-blocking attributes allows shutdown to occur selectively from a simple actuator shut-off to a total plant trip:

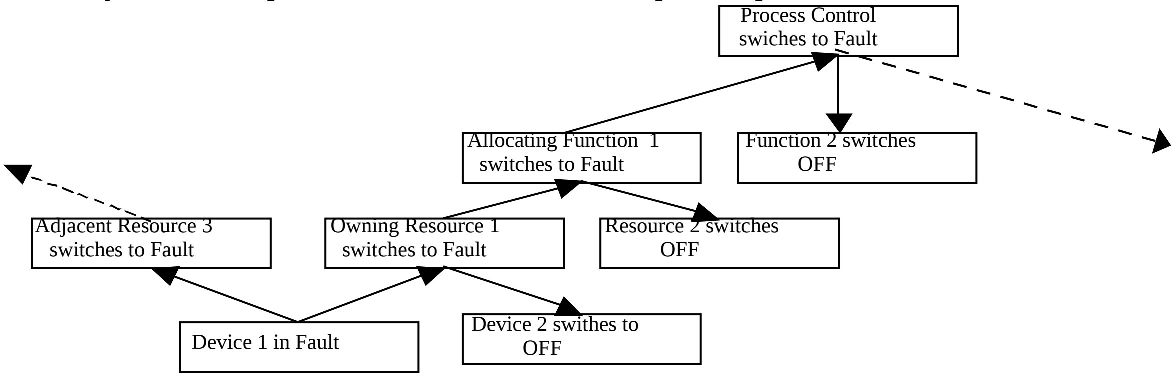


Figure 10

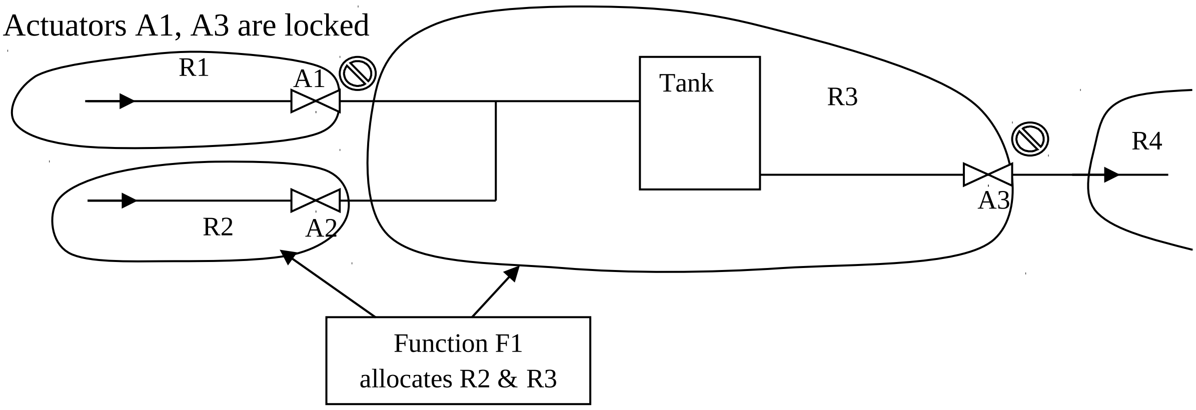
PADLOCK: SECURE OPERATION

Resources are dynamically allocated for making different products one after the other or at the same time in a given process cell. The safety issue is a major concern for preventing products to be mixed by opening a wrong valve.

Flow analysis allows confining interlocks in devices themselves: a wrong operation requested by either the control system or the operator is protected by the “Padlock”. The simple, systematic rule is that an actuator, which does not participate to a flow, is locked.

In the figure bellow, the F1 *Function* allocates Resources R2 and R3 in order to fill the tank.

- Actuator A2 can operate.
- Actuators A1, A3 are locked



PRODUCT / LOT / PHYSICO-CHEMICAL STATUS: TRACEABILITY AND CROSS CONTAMINATION PREVENTION

Resources are the key of Process Flow Analysis, holding fundamental contextual data related to the equipment and the product inside:

- Activity of the equipment
- Physico-chemical status of the equipment
- Product end Lot IDs
- Allocating Function
- User, timestamp

This information may be propagated to any subscriber or requested on demand. The result is a consistent process information framework from the sensor to the business system.

Physico-chemical control prevents a valve to open if the status of the involved Resources may lead to cross-contamination. The following matrix gives an example of Sanitary Interlocks on isolating actuators:

		Upstream Resource Sanitary Status			
		CLEAN	DIRTY	PRODUCT X	PRODUCT Y
Downstream Resource	CLEAN	-	**Locked**	-	-
	DIRTY	-	-	**Locked**	**Locked**

Sanitary Status	PRODUCT X	**-**	**Locked**	**-**	**Locked**
	PRODUCT Y	**-**	**Locked**	**Locked**	**-**

The rules to allocate these statuses may depend on implementation and intended purpose. It is always simple to manage however.

This is a very robust way to prevent product mixing and appreciated in regulated industries. It improves flexibility by allowing a fine equipment allocation comparing to traditional approaches where entire units are confined.

IMPLEMENTATION AND PROJECT METHODOLOGY

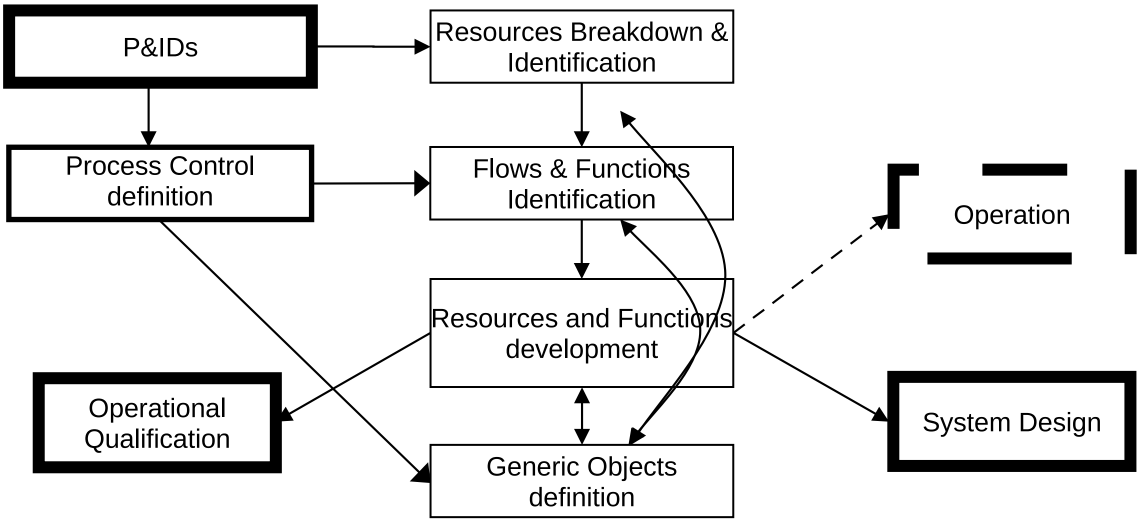


Figure 11

Thinking big is great: systemic approach for problem solving is the way our engineers are taught. At school, problems are well defined: Solutions are exclusively built on the information set provided with the problem. In the true life, especially in Automation, problems are never extensively stated. However, a complete solution is required. That is a big challenge for control engineers: Hopefully, most of the time, the system will work accordingly. Unfortunately, the job is not finish at start up: Process engineers and operators will be probably put out by the behavior of the new system. It will take time before they fully trust it after a laborious tuning, bug removal and improvement period. To make things even more difficult, most of the plants are no longer dedicated to produce the same products in a fixed manner. They must be ready to deal with new products, evolving processes, agile schedules, dynamic optimized routings… They must present their services in terms of processing capabilities rather than as product dedicated facilities. Product making rules are no longer the reference for developing control systems.

This imposed analytic approach is easy to follow and lead to an extensive definition of objects. Starting from elementary equipment entities and their inherent capabilities, the method covers the system development up to the definition of the basic services that a “Process Control engine” can request from the Process Cell.

CONCLUSION

We have illustrated how big, centralized and rigid systems are to be replaced by regenerative and evolving integrated systems made of decoupled, autonomous and quite independent entities. S88 and Process Flow Analysis help Automation Engineering to become well synchronized with the overall engineering effort: Product development leads to P&ID definition and Process Control, while specific local conditions are used to define equipment entities and Equipment Control.

REFERENCES

Related efforts and standards

ISA – The Instrumentation, Systems and Automation Society www.isa.org

- SP88 – ANSI/ISA – 95.00.0x – Enterprise-Control System Integration
- SP95 – ANSI/ISA – S88.0x – Batch Control
- SP50 – ANSI/ISA-50.0x – Fieldbus Standard for Use in Industrial Control Systems

IEC – International Electrotechnical Commission www.iec.ch

- IEC 61499 – Function Blocks for Industrial Process Measurement and Control Systems – Voting draft PAS 2000-03-28 TC65 WG6
- IEC61568 – Digital data communications for measurement and control - Fieldbus for use in industrial control systems

WBF – World Batch Forum, www.wbf.org - “Flow analysis” Working Group

FBF – French Batch Forum, www.frenchbatchforum.org - WG3 working group

References

Rhône-Poulenc Industrialization, “Methodological guide for the analysis of multipurpose batch process plants”, 1994

Flemming Darrin W., Pillai Velumani, “S88 Implementation Guide – Strategic Automation for the Process Industries” Mc Graw Hill, 1999

Cubizolles Bernard, “Vertical integration: Information flow in Batch plants beyond S88”, French Batch Forum Conference, Paris, France, January 2000

Bovée Jean-Pierre, “Valider en suivant… Le fil d’Astrid”, French Batch Forum Conference, Paris, France, January 2000

Grossin Jacques, Rayon Jean-Michel, « ASTRID et la traçabilité native », French Batch Forum Conférence, Lyon, France, November 2000

Lebourgeois François, Rayon Jean-Michel, Vieille Jean, “A Flow Stream Approach for Process Cell Modularization”, World Batch Forum Meeting of the Minds, Atlantic City, NJ, USA, April 2000

Mercier Frank, Lelièvre Daniel, “Traçabilité des ateliers Batch”, French Batch Forum Conference, Paris, France, January 2000

Vieille Jean, « La norme S88.02 : un Langage pour le contrôle des procédés batch », SEE conference, Amiens, France, October 1999

Vieille Jean, « L'Automatique à la fin du millénaire », SEE Annual report 2000