

Methodology of Realization for Supervisor and Simulator Dedicated to a Semiconductor Research and Production Factory

Hanane Ondella, Pierre Ladet, David Ferrand, and Pat Sloan

Abstract—In the micro and nano-technology industry, the «clean-rooms» dedicated to manufacturing chip, are equipped with the most sophisticated equipment-tools. There use a large number of resources in according to strict specifications for an optimum working and result. The distribution of «utilities» to the production is assured by teams who use a supervision tool.

The studies show the interest to control the various parameters of production or/and distribution, in real time, through a reliable and effective supervision tool. This document looks at a large part of the functions that the supervisor must assure, with complementary functionalities to help the diagnosis and simulation that prove very useful in our case where the supervised installations are complexed and in constant evolution.

Keywords—Control-Command, evolution, non regression, performances, real time, simulation, supervision.

I. INTRODUCTION

THE semiconductors industry is in constant progression, the manufacture factories in this domain must face up this phenomenon in maintaining up to date their production line. The quality, the cost of production and the product output, impose some constraints at the resources level, their availabilities and the environment (dust and waste are controlled).

The process of manufacture is complex and involved around 250 successive and different operations all fundamental for the manufactory of only one chip, imposing demands of «utilities» in quantity and in different length according to the stage and the technology in progress.

To answer these variable needs, the factories have a fully-fledged service, the «facilities» (cf glossary) that, in close

collaboration with the teams of the «clean-room», answers continuously the needs of the «Process» service, while respecting the orders and the strict specifications established by the teams of «Research and Development», to get a product finished conforming to requirement.

• Presentation of the STMicroelectronics Crolles II «facilities»

The production of the electronic chips doesn't involve only around silicon, it solicits an important number of variable «utilities» according to the technologies.

These «utilities» are: ultra pure water, electricity, chemicals and gases (for the lithograph and the masks,...), compressed air, process vacuum, hot and cold water. Also, the control of ambiance of the «clean-room» permits the production in optimal conditions. The center of these «areas» is managed by different disciplines: mechanical, «PLC»'s, process, data processing, all regrouped in the same service: the «facilities».

The availabilities of these resources are critical to the working of the «clean-room», due to the complexity of management the diversity of «Control-Command» system put in place. It's necessary to have dedicated experts to development the supervision system, omnipresent on site to implement and support the supervision and to assure its maintenance.

In order to optimize the quality of the service, the «facilities» assure a permanent surveillance of their installation by means of a robust supervision system. However, the implementation of the changes to the supervisor is made difficult by the constraints present on site and that are to consider it in phase of study and integration.

II. PROBLEMATIC AND CONSTRAINTS

A. Problematic Statement

The main mission of the «facilities» service is to provide, in a continuous way (7d/7 and 24h/24), the necessary «utilities» of the «clean-room» for the manufacture. Also, a reliable and effective system of «Control-Command», prove to be indispensable for the distribution of poisonous and dangerous product.

Currently, the available tools don't include the totality of the requisite functionalities. For this reason, it's difficult to support an increase of production «ramp-up», where the

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measures of security are delicate to implement in a context where all operates «on-line», without any tolerance to the security, the errors or the stops.

B. The Constraints

The {Supervisor/simulator} must have a certain number of functionalities and must also follow the evolution of the installation that conforms to two types of constraints.

Constraints necessary to the working of the «*facilities Crolles II*»:

The varied industrial hardware and software by several providers, various material and software solutions (Siemens, Schneider, Honeywell, InTouch, ...).

No stop of factory is programmed forcing the implementation of the modifications in «Run-Time», that makes the maintenances a delicate operation with a high risk that errors impact and stop the process of manufacture provoking an «ITP».

Evolution constraints: The system of «*Control-Command*» must be compliant to the installation that it supervises; it must come with its evolution and/or its extension. These changes imply new points of control, new specifications and the increase in the number of points supervised.

To overcome to a large number of the difficulties met in the implementation and in the insurance of its non regression. The study of the needs concerning supervision and simulation typically conforms to the «*facilities*» service and the establishment of a first version of the tool specifications and methodologies are proposed.

III. STRATEGIES OF DEVELOPMENT

The set of a reliable «*Control-Command*» support can be shown, as the Fig. 1 shows, in accordance with a classic method of studies and conception «*cascade with return*» [02]. The first stage is fundamental because it permits us to establish in detail the needs and to specify the operations that the tool in phase of conception must fill. At the end of this study, a first version of the specifications is delivered and the two following stages can started.

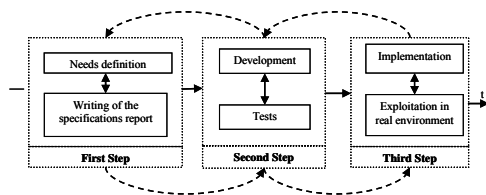


Fig. 1 Principle of implementation the «supervisor & simulator» tool

In the paragraphs that follow, it's described a part of the necessary functionalities to supervise, to order and manage the complex installation, in continuous progression.

A. Functionalities specifications of the «supervisor/simulator» tool

Three important specific needs, concerning surveillance and «*Control-Command*», have been highlighted in the «*facilities Crolles II*» setting: to help exploitation, for diagnosis help and finally the simulation that can be considered like the supervisor's part or a fully-fledged tool that will be put in parallel of the supervision.

1) Functions of the Exploitation Help

To facilitate the daily exploitation of the installation and to make its evolution transparent, some steps must be taken at the time of the creation of the application. Among these measures, the choice of a modular breakdown strategy are mentioned to guarantee the robustness of the supervisor's structure, simplicity of modifications and setting up of the application and identify the coexistent ties between different modules. The modularity principle calls on the generic notion and oriented object development, using the «*P&ID*» as a bases for the synoptic edition.

Also, the tool must have a part dedicated to the management of all type of documentations, among them: the functional analyses, the tables of exchanges, the reports of the tests, the stages of starting of the applications, «*P&ID*», the different general or specific procedures, the different versions of the «*PLC*» programs and all reports of evolution concerning the installation.

Also, the maintenance procedures that detail the list of tasks to do are available on-line, to help the exploitation team. Indeed, the errors during the maintenance are not negligible. The majority of the recording impacts that have brought production to a standstill, due to human errors committed during the routine interventions. Also, the industrial experience shows the interest to equip the tool with «plans» on-line, in order to make more easily to locate the equipment «*facilities*» and facilitate the communication between two different teams during intervention.

In the exploitation phase, which represents the major functionality, the «*Control-Command*» means the two fundamental tasks confided to a supervisor and to reach there, the control requires a reliability of the information while assuring their continuous updating. This surveillance will permit benchmarks between the required and current states in order to detect any failures.

The exploitation in critical industrial environment requires the establishment of the control plan and the «*SPC*» with the aim to provide the compliant products and services to the «*process*» specifications for every «*area*». In the same way, for the maintenances traceability, it's important for the technicians in control room to know the «*facilities*» elements in maintenance (equipment, pump, filter,...) and to be able to judge the better priority to grant to an alarm occur to the equipment under intervention. For it, a «pop-up» dedicated to the maintenance, permits to collect all information concerning the equipment (the brand, date of beginning, length and date of intervention end). To store all of these requirement data fields allows the assignment of a new color code to the

equipment requisitioned and alert to exploitation team if the working deadline has been expired.

2) Functions of Diagnoses Help

Today, the industrial claims the lack of well diagnosis tools offered with the supervisors and the inability of these to support a new addition of a complex algorithms to the already existing applications.

Among the diagnosis tools that the new support must provide: the dedicated filters to analyse and treat the alarms, because their recurrence can reveal a start of failure or permit to identify system fragility. It's necessary to create a filter permitting to establish statistical analysis, like apparition frequency and length, in order to be able to do the preventive diagnosis and studies for avoid an undesirable event.

The other idea is also to exploit to the maximum the means diagnoses offered by different equipments and the «PLC». In this perspective and in the case of the «PLC», it's necessary to adopt a uniqueness of the diagnoses for all «areas» and to create a generic diagnosis modules, that will be redefine and adapt to kind and supplier «PLC».

For the same reason as the different parameters and alarms recording, a database targeted for help in according with «make decision by experience capitalization» is created. The goal is to collect in one or some database all information: default sources, troubleshooting method, symptoms, statement of measures, preventive and curative solutions. This information group offers the possibility to construct some rules permitting knowledge conservation, transmission and offering a diagnosis help. It's a viable and non frozen database, the teams should review and complete when some new elements allow it.

The system of distribution is not protected from the material or software failure. Also, with the view the impact that parameter drift can generate comparing to its reference behavior: stop of distribution and/or dangerous and toxic products leak... It's important to accentuate the controls via algorithms [4], in substitution to the material redundancy because it represents an elevated cost. These algorithms lean on the measures in real time and do some comparisons in relation to pre-established nominal models and alert in case of over consumption, absence of regulation or other singular behavior.

3) The Simulation Tool

In addition to the control for the surveillance, the command and the diagnosis, the simulation is added to all the functions mentioned in the previous paragraphs, to complete the «supervisor & simulator» tool. Indeed, the semiconductors production imposes some environment constraints and also to the resources availabilities, what implies the necessity to have a tool of tendencies calculation, which allows the operators to do the estimable calculations and predictive studies in order to limit errors.

Let's remember that the «facilities» installation are in continuous evolution to meet the needs of «Research & Development», «Manufacturing» and except during starting

phase factory, it's impossible considering the principle and the constraints of «clean-room» working, to stop an equipment in distribution, to do some predictive material tests and checks or study impact.

That's why, today, a support and simulation tool by «failure injection» is necessary for know installations, handle the failure impacts, evaluate and adopt some solutions at every level: better and earlier failure identification and faster troubleshooting.

In this section, the implementation of the simulation part is proposed to allow the different contributor:

- To study the impacts that can occur following a material or software failure.
- To propose some solutions to solve simulated failure and to come back to normal or acceptable state.
- To write the adequate and target intervention procedures.
- To manage the spare-parts on site, according to the installation or equipment importance.

This tool part is transparent in relation to the distribution system; it's making in parallel of the supervision system in normal working and doesn't introduce any disturbance into «control-command» system.

a) Principle of Simulation Working by «Failure Injection»

Two possible ways of working for the simulator tool exploitation can be listed:

First way: while using a test «PLC» compliant to the one used on site

Second way: while privileging the dialogue exclusively between supervisor and simulator.

Each of the two configurations has their advantages and inconveniences and to give more importance to the first one than the other one is the result of a compromise solution goes by selection criteria established by the constraints and the objectives aimed by the simulation that is done.

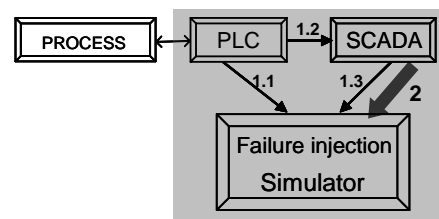


Fig. 2 Communication principle between the supervisor and the simulator

The drawback of the first solution is relating to the additional cost and to the implementation difficulty within an installation equipped with various «PLC» brand and manufacturer as is the case at STMicroelectronics.

Thus, the predictive studies simulation requires the knowledge and expertise in multiple «PLC» languages to do the new functional analysis programming to test.

On the other hand, the second way implies only the supervisor and the simulator provided with the «PLC» model

can prove to be sufficient to do «failure injection» or all other event simulation.

b) *The Simulation Tool by «Failure Injection»*

The tool proposes to simulate some failures on virtual images of the «real processes» already existing but also through predictive studies that include the new extensive, preventive (put in place redundancy solution) or curative solution implementation.

On principle, the spare-parts and the failures occurrence will be considered like unpredictable parameters and it's supposed that the studied system is not to be prone to raw material ruptures: no chemical drum supply problem for example.

1) *Notion of dreaded script*

The goal of the tool is to carry out the failure simulation of through both dreaded and nominal working scripts.

A dreaded Script will be described by the following elements: {Initial State, final or undesirable State, history / course / disruption that describe the evolution of the studied system}.

To be able to judge that a script is dreaded or no, it is necessary to define the nominal scripts, establish from the functional analyses represented in the form of «*Petri Nets*» [2], [3] and that will use like referential for the first stages of comparison and diagnosis.

Identical to the dreaded script, a nominal script is describes by the threesome: {Initial State, nominal final State, nominal course without disruption}, with as particularity, the initial state that is common with the undesirable scripts.

2) *Affected failure categories*

The exploitation team is able to face different failures types, with a different and variable critical order. Indeed, the failure can occur on a material with or without redundancy solution, it can bring the system therefore to function in damaged way or then to paralyze it during a ΔT length, equivalent in the «*MTTR*», necessary to repair and to make the installation operational again.

However, at the start of our study, two failure types has distinguished, a first that will be localized to the equipment level (distribution cabinet, valve manifold box,...), that's called «Process Failure» and another type occurred to the «*PLC*» level and that it's designated by «*PLC Failure*».

According to the type of failure to treat, it's intended to differentiate the «*PLC*» model that can be established. Indeed, it is useless to consider the «*PLC*» in a complete and complex configuration, if the simulation goal is to treat the failure material met on equipment.

3) *Notion of the «PLC» model*

The distinct classification of the failures category suggests to proceed to two modelling of the «*PLC*» according to the simulation requires.

The configuration of the «*PLC*» model will be creates with

the help of the databases dedicated to this function and the defect simulated will be injected in the model describing a given task, in order to not to limit the investigation to the «*PLC*» level but to widen them to the installation to measure the real impact generated by the «*PLC*» failure.

Model of the «*PLC*» = Black Box, using for equipment failure, it doesn't take into consideration that the necessary elements to the simulation, for example: I/O, variables addresses, response time to answer request, «*PLC*»...

Model of the «*PLC*» = real model, using during «*PLC*» failure simulation, for a modelling faithful to the reality, it will be interested, in part or in totality, to material, software architecture and network.

However, it is useless to consider all hardware blocks of the «*PLC*» if it aims a particular failure doesn't affect the set of the elements of the «*PLC*».

4) *Configuration and supply of databases*

The tool is provided with various, non frozen and adjustable databases, classified by categories. There allow the user to create a specific simulation and to complete some bases in according to the established diagnoses and the adopted solutions.

- «*Process*» database represents main process functions. It regroups a set of the nominal script representing the ideal installation «*facilities*» working.
- «*PLC*» database: This one allow user to create a «*PLC*» model in accord with his need. Indeed, this paper proposes two models «*PLC*» configurations, «*Black Box*» and «complete configuration» used solely for simulation without a «*PLC*» test.
- «*Process*» and «*PLC*» failures database.
- Spare-parts database, regrouping the needs, availability and kind of different material.
- Solution and methodology database. It lists the diagnosis results, the rules and the procedures written following every simulation.
- Performance parameters database. It brings some evaluation indicator in according to performance and safety system.

The principles stages of simulation have developing in the following part:

- Firstly, identification the «*area*» of the «*facilities*» and part of «*process*» concerned.

Secondly, selection for the nominal «*Petri Nets*» in the dedicated database (otherwise, to create the referential «*Petri Nets*» if it's doesn't existing) [VEN, 95].

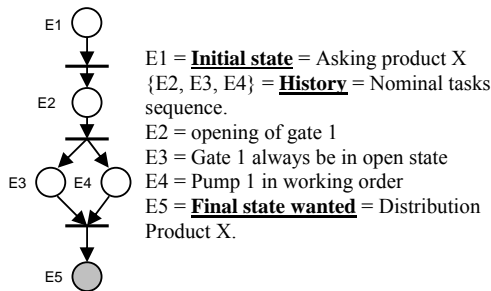


Fig. 3 Nominal distribution Product «X» model

- Extract from the nominal «Petri Nets», the essential elements set of offering a good working. The method suggests to limit ourselves to the material «process» inventory {gate, valve, detector, pump...} because in automatic side, the problematic will be the same any «Process» concerned. The nominal tasks succession that the system must to do to achieve one's mission is enumerated.
- The user's simulator can work with the choice of a dreaded final state or being interest to the consequences due to the material failure or software failure for only one «facilities» elements studied [6].
- At the end of every simulation, a report is published and stocked for ulterior consultations. It includes the category of simulation done, the deviation from the norm, the predictive simulations references that can be followed the main simulation to test the relevance of the modifications. Also, the user can inform the set of the actions that have been taken following this simulation, as the procedures writing, the plan maintenance modification or other....
- The non negligible simulation target is to allow the expert to visualize the simulation results, through a familiar tool. In our case, the simplest solution is to use like visual support, the existing «SCADA» application, that act as strengthened basis to control «facilities». The communication between the supervisor and the simulator can lean in the same way on the exchange of data type that the addresses «PLC» and the «tagname» commonly used for the supervisor development.
- At the end of this first phase, a specification is written to permit the developments to begin and it will be change according to the customer demands, the technologies used and other parameters lies to the real locality exploitation of the «Supervisor and Simulator» tool.

B. The Implementation Tool

To guarantee to the user complete tool for exploitation, the implementation phase proves to be difficult and critical, so much on the volume and the number of the applications to treat, the number of points and remote controls to verify, that on the methodology to follow to assure correct result.

The study proposes test tools coming to insert between the development phase and the test phase in order to do a primary tests and evaluation campaign without installation or integrator monopolization and so to minimize the errors which need to be corrected on site.

In this part, a first tool that named «FMCS SIMULATOR» was achieved which performs a comparison between the dictionaries and the exchange tables, to find anomalies like the topics defaults and the wrong attributions «tagname» or any error that can provoke a no compliant exploitation.

Also, it provides the possibility to test the remote controls, to verify the groups and the good assignment of the alarms priorities following the development of the scripts of failings that the different «facilities» could meet during their exploitation on site.

FMCS Simulator

Today, the available functionalities, via the simulator and that can be implement on «InTouch» supervision application are:

- Comparison of the evolution of the dictionaries of same «InTouch» application, from two different «N» and «N+1» versions. The first functionality permits, among others, to test the evolution of supervision application, by comparing the whole or one part of «tagname» declared in the simulator...
- Simulation of changes values and remote control tests scripts, in a disconnected context of the production, to assure a large tests reliability without impacts on the working systems.
- Espionage and forcing values: after having selected the «InTouch» reference application and during its execution on the work station, this tool allows to select and to supervise on-line the application «tagname» then, while proceeding to the modification of one or several values of its «tagname» and to see the direct repercussions on the application.

As the below figure shows, «FMCS Simulator», is put in parallel of the present organization and doesn't disrupt on any case the good progress of the various supervision tasks. This software comes to help the modifications demands and the operative procedures validation in «off-line». It allows simulating, with the «failure injection» method the likely cases but difficult to provoke as the default material, to test the anomalies detection their diagnosis.

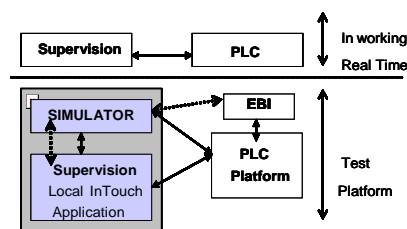


Fig. 4 Comparison of two «Control-Command» system structures in production and in test

In spite of the precautions taken to provide an efficient and reliable tool, some mistakes and anomalies can subsist and create ulterior bugs or overload some communication or «CPU»s cards, making the treatment time longer and insufficient to supervise «facilities» in optimal conditions. To be able to control and supervise of all quality deterioration of

the service returned by «Supervisor & Simulator» system, it is useful to establish a control panel summing up the set of the performances to maintain on all levels of the «Control-Command» system.

The method consists in doing some measures in starting application phase and before every new important implementation or modification. The nominal references has been given and a periodical statement is doing that it compares progressively to make the diagnoses followed by the necessary modifications to maintain a product output quality and the equal performances to the requisite results.

C. Test and Final Implementation of the Supervisor

The last stage that intervenes in the «Supervisor & Simulator» implementation during its integration in the real environment working. It's composed of some actions categories: tests and readjustment according to the reality, site and user conclusions. It is a part of methodology and exploitation follow-up, notably while writing a set of documents concerning the applications and software «upgrades» to foresee, without forgetting the servers and all equipments tests and maintenances can undergo.

IV. CONCLUSION

This article highlights the complexity of the complete tool implementation that will assure the keys mission of it «Control-Command».

It puts the emphasis on the difficulty that grows with the fact that the tool must evolve in strong expansion context, where each modification of installation is accompanied by «clean-room» «ramp-up» and needs increasing. It underlines the seriousness of the tool implementation stage, while being careful to preserve and to respect the homogeneity of the new in relation to the existing.

GLOSSARY

EBI: Enterprise Building Integrator, integrated facility management solution. (Developed by Honeywell)

Facilities: service dedicated to assure the utilities distribution.

Firmware: is software that is embedded in a hardware device.

FMCS: Facilities monitoring control system, some materials and software setting up to assure the installation supervision.

InTouch: Supervision tool of Factory System.

ITP: Interrupt To Production.

MTTR: Mean Time To Repair.

Process: conceptual technology range, (Process team, team loaded of implementation of these ranges)

Off-line: term used for designer the analyses that take place in a basis of disconnected time of the one of the process analyzed.

P&ID: Plan and Instrumentation Diagram

PLC: Programmable Logic Controller

Ramp-up: Increase, as with activity or production.

Petri Nets: is a formal and graphical appealing language which is appropriate for modelling systems with concurrency

SCADA: Supervisory Control And Data Acquisition.

SPC: Statistical Process Control

Upgrade: means a replacement of hardware or software with a newer one, in order to bring the system up to date.

Utilities: some resources (except silicon) necessary to the semiconductors production.

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