CONTROL OF ADVANCED MANUFACTURING SYSTEMS

Adrian CURAJ, Aurelian Mihai STĂNESCU

Politehnica University of Bucharest - Human Resource Training Center,
Bucharest, 132 Grivita St., Sector 5, Phone/Fax: 3113241/3113242
e-mail: adi@cncsis.ro

Abstract : *The desired improvement in performance and the realization of global enterprise objectives require a tight integration of the units of the enterprise. This integration could be achieved by improving the information flow both horizontally and vertically. The close monitoring of the operational performance of process plants, their associated instrumentation and control is seen to be of increasing strategic importance. Failures can lead to increased costs, reduced product quality, consistency and production, plant shutdown, an increased environmental impact. It is a real need for the advanced monitoring technologies to be applied, and their potential demonstrated, on complex industrial plants. The paper discusses some key issues concerned with the SCADA oriented for advanced manufacturing system.*

1. INTRODUCTION

The manufacturing environment is typically seen as a large , complex, man-made system of heterogeneous, interrelated activities. Designers, planners, operators, workers are organizationally integrated within manufacturing system. The use of computers, communication techniques, real time distributed database technology, modeling and simulation driven design of automation system, real time models from controlling the individual machines (involving more and more intelligent functions), the manufacturing cells and shop-floor to planning and control of Fabricators [1] integrated in Virtual Enterprise alliance has opened the challenging way to develop the flexible industrial integrative platform based environments for SCADA system configuring and development manufacturing control system supports the technologist in searching for an optimized manufacturing schedule which takes into account all the terms of meeting supply and delivery times, maintenance schedules, machinery conversions, etc. The decision making process uses the past (historian) information recorded by the distributed process data acquisition system and the simulation software information. The advanced manufacturing systems ask for new solutions, aiming:

- to implement adaptive autonomous control, with respect to various uncertainties within the manufacturing environment due to unforeseen factors (wear and tear, error-prone operator commands, customer driven changes)[2];
- to promote the synergistic coordination such as the operators and machines could help each other to achieve a result of which cannot be achieved individually by either or them [3], according to the highest man-machine synergy possible;
- to support the intelligent control based on the neuro-fuzzy techniques and genetic algorithms for performing the automatic learning complex tasks [4].

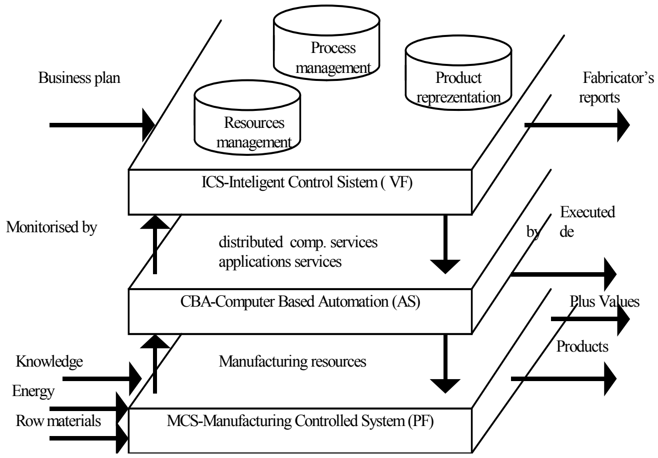

Fig. 1. *Fabricator.*

The Virtual Factory (VF), as a is a promising framework to implement these emerging technology-based manufacturing systems. The VF-oriented approach is not diverging trend in comparison with the state of the art topics within the Integration in Manufacturing. The dynamic extended enterprise, the holonic systems-based enterprise, the fractal enterprise, the bionic and agile manufacturing systems are some of the main important fields of advanced contributions in this field [5].

2. THE FABRICATOR

Fabricator is a autonomous agent offering products and services on the business market. It is required to perform all activities to achieve the business goal-structure according to the selected strategy and policies. The concept of Fabricator involves the following hybrid system integrating three layers architecture [6]:

Virtual Factory is the software models and applications system describing, in virtual environment, the dynamic behavior of the real manufacturing system aiming:

- To assist strategically/tactical/ operational decision making process;
- To develop products/processes/ manufacturing facilities;
- To develop automation control system;
- To develop processes management and resources management.

Automation System is the integration platform-based system that maps the virtual manufacturing processes, ordered by a scheduling plan , into a spatio-temporal activity pattern. It works according to an optimum dynamic task allocation of manufacturing resources.

Physical Factory is the programmable manufacturing system, comprising the heterogeneous resources:

^{P}R - the Producers set
^{T}R - the Tools set
^{M}R - the Movers set
^{C}R - the Carriers set
^{S}R - the Storage set
^{H}R - the Human set
^{W}R - the work in progress parts set

3. CONTROL OF MANUFACTURING PROCESSES

The reference input data for manufacturing control are provided by the supervisory MRP (Manufacturing Request Planning) system and the control deviation is observed by the process data acquisition mechanism. This is the A control loop in figure 2. When it is looking for an optimal manufacturing schedule the starting point is the real time process information database, where there is the whole processes history. In order to predict the manufacturing system

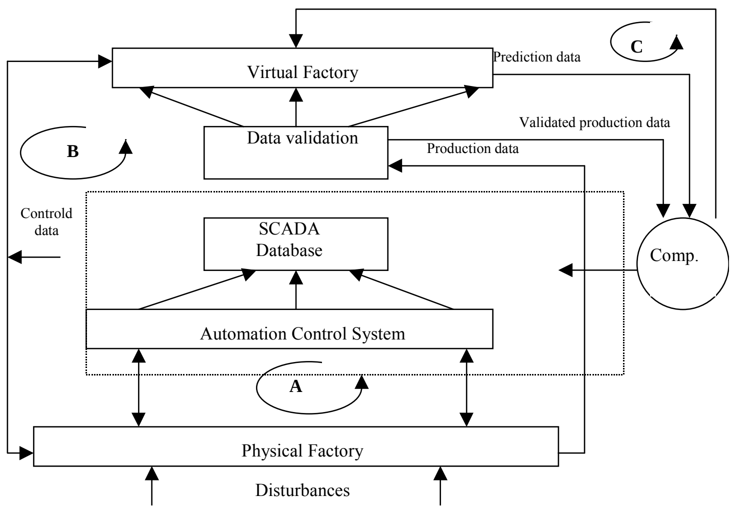

Fig. 2. *Fabricator- Supervisory control system architecture.*

behavior under a established control schedule it is necessaries to simulate the process. By simulation can be compared different manufacturing scheduled aiming to chose the optimal schedule. The A control loop is supplemented by B control loop which contain the RTM (Real Time Model) of the manufacturing system. A real time model shall be provided with the characteristics as following, but not limited to:

- Incorporate field proven technology system architecture;
- Allow for future expansion;
- Provide ease of operation and maintenance;
- Provide timely and efficient response to both anticipated and unanticipated demand and supply changes;
- Provide the capacity to easy recognize and rapidly respond to operational problems and effectively minimize their impact;
- Efficiently maintain data describing historical physical factory operations and permits quick retrieval of this information.

Under the normal manufacturing conditions more and more increasing difference will arise between the simulation results and the manufacturing processes. This is due the stochastic influence such as express job orders or machine breakdowns as well as

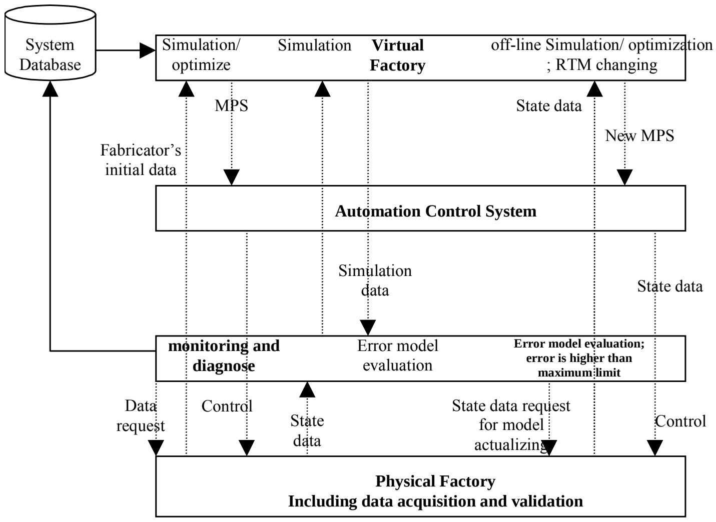

Fig. 3. *Informational flow for SCADA.*

inaccuracies of the manufacturing model (e.g. not exactly known working, loading/unloading, calibration times etc.). It have to be controlled also the RTM itself and also its initial data. The C control loop, an off-line one, is in charge with control of the model [7].

The information flow aiming to support the SCADA system is presented in figure 3.

4. SCADA SYSTEM SPECIFICATIONS

The proposed SCADA system for control of manufacturing activities [8] is consisting of (figure 4) the following :

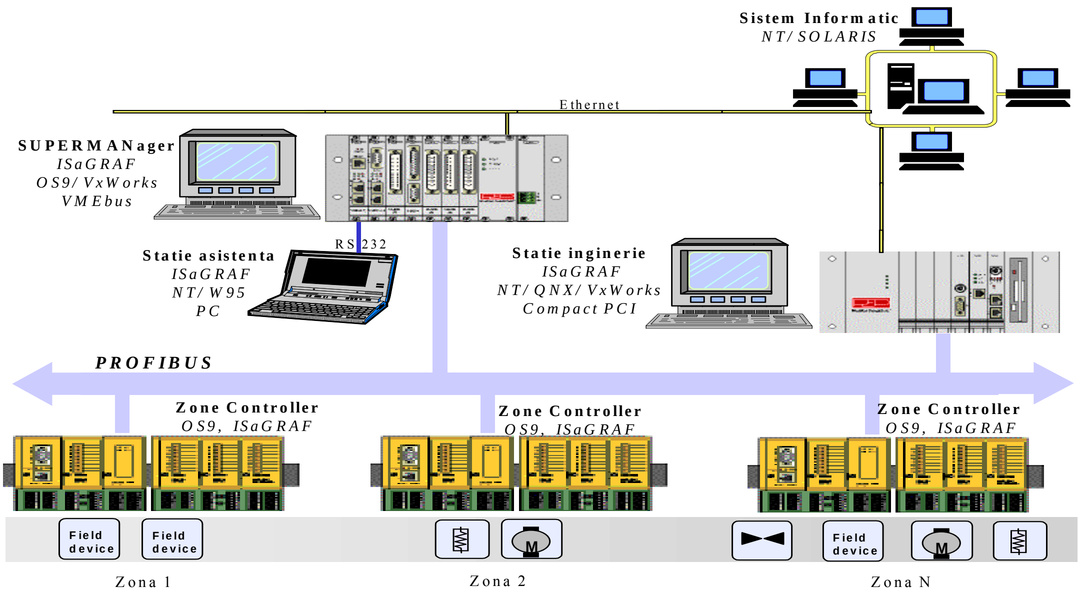

Fig. 4*. DCS-SCADA control system*

Zone Controllers (ZC)
Communication Buses
Super-manager
Man-machine interface
Engineering workstation
Technical assistance workstation

A proper SCADA-DCS (Distributed Control System) have to give real-time information from the Physical Factory to the management and control system at right time and right place for, and not restricted to:

- Control of manufacturing facilities;
- On line monitoring of technological parameters;
- On line monitoring of row materials flow;
- On line monitoring , data validation and recording of the manufacturing data;
- Monitoring and recording of the alarms / failures;
- Recording of maintenance information for shop-floor facilities.

The proposed hardware solution is based on VME architecture as following:

VME Characteristics		
Architecture	Master/slave	
Transfer Mechanism	Asincron	No central clock for synchronizing
Addressing	16, 24, 32, 40, 64 bytes	Dynamic selection
Data	8, 16, 24, 32, 64 bytes	Dynamic selection
Error detection	Yes	BERR signal
Data transfer rate	0 - 500+ Mbytes/sec	
Interrupts system	7 levels	Interrupt vector
Multiprocessing	1 - 21 processors	Flexible arbitration; multiprocessing
System diagnose	Yes	Using SYSFAIL signal
Plug & Play	Yes	Under VME64 & VME64x
Max. no. of slots	21	Limited to the 19" rack

The Software solution is based on OS-9 Unix-like operating system with the following proprieties: multi-tasking, real time (tasks planning, resources allocation, interrupts control, I/O control), modular (three levels of modularity: kernel, file manager, drivers), an unified I/O system, inter-process communication system, high performance, compliant to new hardware configurations, having a fulfill management and resources allocation functions set.

DATABASE REQUIREMENTS

Simulation software must exhibit clear functional divisions and object orientation. All data, supervisory commands and parameters acquired from SCADA system and all data, supervisory commands and parameters to be output to the SCADA system are stored in a comprehensive real time, relational manufacturing system simulation data base. The real time manufacturing simulation database resides in a file system and real time memory resident database. Additionally, certain information are extracted from data files and maintained in shared memory regions to allow fast access.

The SCADA real time system database shall be the common data interface between all active program elements in the computer system, including the data acquisition, operator interface and manufacturing application software. As the common interface, the SCADA real time system database shall include all information necessary for the proper operation of all application programs. The data available shall include program calculated, operator entered, data-logged and historical data. The capDCS-SCADA control systemability shall be provided for third party software modules and for commercial database programs to access the real time manufacturing simulation database.

SIMULATION INPUTS/OUTPUTS SPECIFICATIONS

Input/Output requirements are the means by which the manufacturing system simulation software presents results to the operators and also the operator controls the simulation software.

Selected simulation data are placed into the SCADA database. The selected data shall be treated and processed just like polled data. The selected data shall include supervisory control commands, parameter changes, incoming simulation results.

Selected SCADA data are placed into the simulation database. The selected data shall include supervisory control commands, parameter changes, incoming field measurements.

The above data transfers are transparent to the operator. The operator receives and sends information through the SCADA operator interface.

DATA VALIDATION

The Data Validation procedure ensures that a well defined basis is being used for all the manufacturing system simulator functions.

The Data Validation procedure uses SCADA supplied data quality indicators, historical data, and instruments repeatability information to provide validated field measurements for the Real Time Model. Each field measurement obtained from SCADA is subject to the validation process after each scan. The data validation procedure evaluates and modifies the status of incoming SCADA data and provides optimal estimates for invalid and missing data. This will allow the RTM to continue in operation even though some values may not be updated by SCADA on a given scan. It is expected that the steps shall include:

- Locate and correct any time skews in the SCADA data and correct any known offsets or gains in the incoming data. In order to eliminate time skews, the RTU software captures the data at predetermined time/frequency and time stamp it. The validation software issues special, high priority polls to retrieve the data;
- Limit testing of the incoming data values;
- Discrepancy analyses of the actual data to the calculated data;
- Estimation or interpolation procedures to provide missing data.

The Data Validation process will produce an alarm when an invalid or unreasonable data point will be encountered.

5. THE EXPERIMENTAL SET-UP

There are different other different aspects that we have to take into account when a SCADA is proposed: look-ahead model (LAM), predictive model(PM), deviation analysis module, system training module etc.

The experimental set-up offered by FABRICATOR framework (a research project on virtual enterprise topics, financed by Word Bank), figure 5, gives the possibility to implement, test and validate different solutions for an advanced manufacturing control system, including SCADA for manufacturing system integrated in virtual enterprise architectures.

CONCLUSIONS

The present paper describes conceptual framework for SCADA system for advanced manufacturing systems exploring the basic concepts involved in control of Fabricator entities integrated in distributed manufacturing systems, e.g. Virtual Enterprise. The research aimed to find out an appropriate system architecture, proposes a three loops SCADA control system architecture and gives a view on SCADA system specifications.

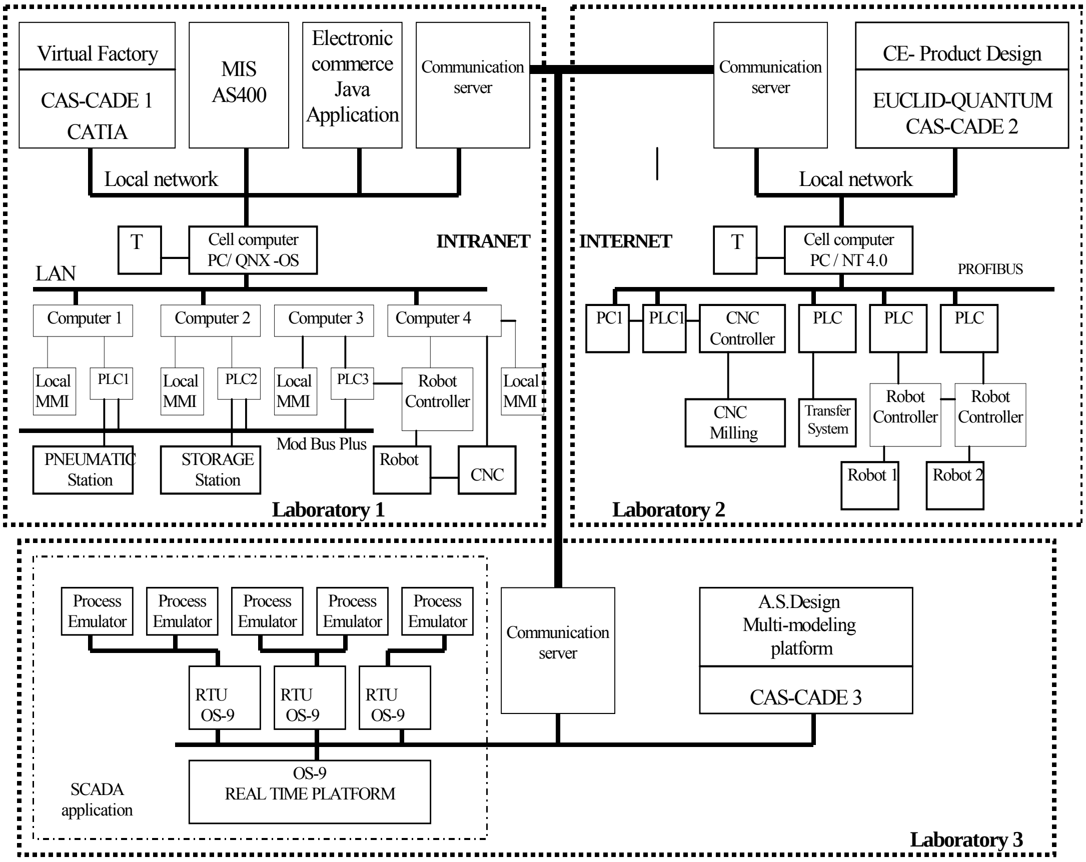

Fig. 5. *The FABRICATOR experimental set-up*

Note: The present paper is a result of the work done in the framework of "Virtual Laboratory – Pilot Project for Research in Advanced Manufacturing Systems Integrated in Virtual Enterprise" , "FABRICATOR" research projects financed by Romanian National University Research Council.

REFERENCES

[1] Curaj,A.(1998) *"Control of the Manufacturing Systems integrated in Virtual Enterprise Architectures"*, Ph.D thesis, Politehnica University of Bucharest.

[2] Lin,G.Y. (1993) *"Distributed Production Control for Intelligent Manufacturing Systems"*, PhD. Thesis Purdue University, West Laffayette, May 1993.

[3] Levis,A.H. (1994) *"Migration of Control in Decision Making Organizations"*, Inform. Decision Technology, No.15, 1994.

[4] Dumitrache,I. (1995) *"Genetic Algorithmes for Intelligent Control Systems"*, PUB. Publ.House, Bucharest.

[5] Stănescu,A.M., Dumitrache,I., Curaj,A. (1997) *"Multi-mode based system design within virtual factory synergetic framework"*, Proceedings of the 4th International Conference on Concurrent Enterprising, ICE'97, The University of Nottingham, UK.

[6] Raulefs,P. (1994) *"The Virtual Factory"* Proc. of 13th World Computer Congress '94, vol.2, K.Brunstein, E.Raubold (Editors) Elsevier Science B.V. (North Holland) pp.18-32.

[7] Sauer,W. (1997) *"Optimization of manufacturing processes by process accompanied simulation"*, The European Conference on Integration in Manufacturing.

[8] Hannam,R.,(1996) *"Computer Integrated Manufacturing: from concepts to realisation"*, UIMIST, Manchester, Addison-Wesley.