FROM SINGLE LOOP TO COHESIVE PROCESS CONTROL: THE FUTURE

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ABSTRACT

Advances in Process Control, Dynamic Solutions and Industrial^{IT} raise the potential for Cohesive Control. The seamless integration of continuous, batch, manufacturing, robots and electrical process control. Tomorrows process manufacturing will demand Cohesive Control.

KEYWORDS

Process Control, Dynamic Solutions, Industrial^{IT}, Cohesive Control.

1. INTRODUCTION

"Smart people learn from experience, wise people learn from others".

The 1st South African Process Control Conference is an appropriate opportunity to reflect on the author's experience of over 30 years applying process control in the process industries, observe the technology developments and offer a prediction of the future.

This is based on significant developments in: -

Process Control
Process Modeling
Industrial^{IT}

These developments, combined with the ever-increasing speed and power of computation introduce the potential for **Cohesive Process Control.** This is the position where Continuous, Batch, Life Science, Robotics, Manufacturing and Electrical Processes are all controlled as a truly integrated seamless activity.

1.1 Evolution Over the Past 30 Years

Process Control

Over the last 30 years process control has developed at a very impressive pace. My starting point was the single loop frequency analysis based approach of Ziegler and Nichols (Reference 1), derived from work in the developing communication sector for tracking changes.

It was in the 1980's when Professor Manfred Morari spent a short period with myself at ICI that I first became aware of Model Based Predictive Control using an inverse process model to implement control. This work (Reference 2) has now become dominant and it is almost "the standard" for the control of continuous process plants as rapid advances in computing power made the computation practical. The benefits on large continuous plants have been significant and a number of commercial packages like Operate^{IT} – Predict and Control are now available. It does however have a number of limitations: -

- Developing and updating the model may be very time consuming and expensive
- It is less applicable to batch, manufacturing or electrical processes.

Recent developments in Parametric Control (Reference 3) offer the potential to apply the benefits of model based predictive control to the very fast processes such as Robots, Manufacturing and Electrical operations. This is achieved by mapping the total operating space into a set of "pixels" within each of which is an optimum control regime. This precludes the need to solve the model every time, bringing the speed of action required for very fast response.

In the Manufacturing Industries process control adopted a different approach based on Statistical Process Control. This was particularly beneficial to Univariate processes found in Manufacturing, with concepts such as Six Sigma operation becoming prominent. The process industries are usually multi-variant. Research at Newcastle upon Tyne University (Reference 4) and others has developed Multi Variable Statistic Process Control (MVSPC) This applies the concept of statistical process control to the process industries.

Batch process control has to some extent received less attention as it is a much more complex task than that of continuous plants. The state of the plant, and hence any dynamic model, is continuously changing through the batch. Equally there are many more options to run and the whole control scenario is difficult. Now with the increasing computing power, and developments in on-line analysis based on frequency based smart analysers and chemeometiric mathematics the potential for real time optimal control is practical. In addition MVSPC is of growing in importance in the batch and extrusion based film processes

In my experience power electrical engineering has been a separate function within most companies and universities. The consequences of failure and the speed of response required at 50 Hz have limited the application of control. There are exceptions like variable speed drives where the process control is very sophisticated indeed. With the developments in the 90's in computing and communication speed it is now practical to apply "DDC" to electrical supply. While the initial applications are for the control of emergency response to supply failure, this potentially opens up a whole new area of Process Control.

This journey is summarised in the figure below.

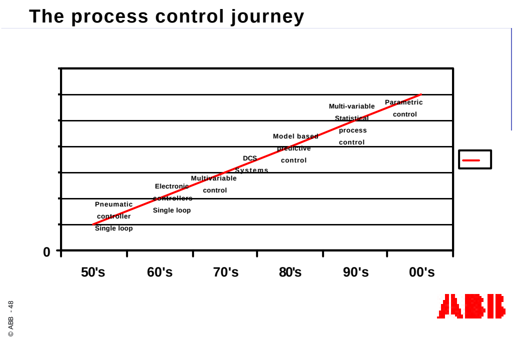


Fig 1 – The Process Control Journey

1.2 Process Modelling

The process industries involve some form of chemical or physical transformation. These transformation processes are often non-linear and may be poorly understood. This has made the preparation of a rigorous dynamic process model difficult and time consuming.

It was in the early sixties that Professor Roger Sergeant at Imperial College (Reference 5), ICI and others started to explore the potential for using computers to solve the basic steady state unit operations of chemical engineering. Prior to that graphical techniques were used to design these unit operations such as distillation columns. Given that the model of a distillation column is a series of counter current equations, this was ideally suited to the early digital computers.

The incentive was to significantly reduce the time and effort involved while improving the design accuracy. Models were totally steady state but nonetheless proved of great benefit. The techniques used involved flow sheeting languages that have since evolved into the solutions now offered by companies like Aspen and Hyprotech. A feature of these early models is that they solve the equations in a sequential manner that follows the process flow sheet. E.g. solve the reactor equations and use the outputs as the inputs to the distillation column. While this approach felt intuitively correct, the drawback was that the iterative solution could be time consuming and unstable. Over 20 years steady state modeling moved from research to the norm in the industry with a vast increase in solution productivity. The vast majority of process engineers now use some form of steady state modeling as the normal tools of the trade. This includes the Process Engineering Library (PEL) (Reference 6), which was originally developed by ICI and is available from ABB and larger packages available from companies like Aspen.

In the late seventies increasing computer power, plus research into the basic mathematics and chemical engineering, encouraged researchers to consider the solution of dynamic processes models. Again Imperial College was the leader and the result was the "Speed Up" product (Reference 7) This was eventually licensed by Aspen and is now a standard product that is available on the market. One of the drivers was to improve the process control of the chemical processes. As a generalization, chemical processes have considerable capacity within them in the form of tanks and storage etc. This often means that the dynamics are relatively slow; hence it was possible to tackle dynamic control problems using model, which solve in minutes.

At around the same time, the concept of simultaneous equation-based solution was developed. In this approach all the model equations are solved simultaneously. This brings real benefits in accuracy and speed. In the nineties the concept of combing equation-based solutions with dynamic models was developed, again by Imperial College (Reference 8). The result is g-proms, which is the latest development in dynamic modeling and flow sheeting. ABB have had an exclusive license for this technology in the automation area and have worked in partnership with PSE to develop Optimize^{IT} - Dynamic Solutions, a "One Model" robust approach for the process industries.

The "one model" approach is based on the principle that the same model is used for steady state process design, control design, commissioning, operator training, operational control and optimization, dynamic data reconciliation, “what if” and safety studies. It has been the vision for many years and now Optimize^{IT} - Dynamic Solutions makes the vision a reality for the first time.

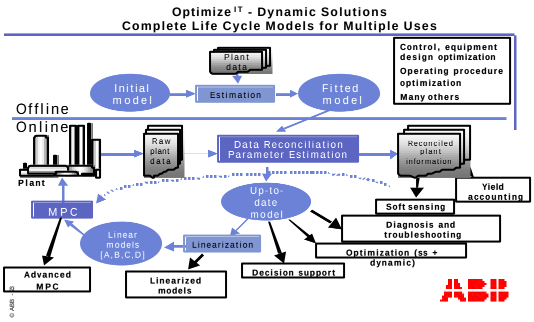


Figure 2 – Complete Life Cycle Models for Multiple Use

All the heat and mass balances of the process are solved every time. This ensures the Dynamic reconciliation of all the measured and inferred process variables without having to wait for the process to attain steady state. This has numerous advantages to the user in the form of accuracy, removal of arguments on yields etc, ability to monitor leak detection, instrument failures, heat exchanger efficiency as well as the option to provide a “fit and forget” model based predictive control.

A key component of any process model is accurate physical properties data. Initially government laboratories developed these models. These have now transferred to private ownership, which develop and manage the core physical properties used by many of the process mathematical models. Within the Optimize^{IT} - Dynamic Solutions framework is a Robust Thermo feature, which ensures that the thermodynamic properties equations do not break down during the solution/iterations.

The evolution of process modeling over forty years has led to a position today where it is possible to model dynamically almost any chemical process and the use of library modules has increased productivity. It is now also possible to apply the latest advanced control techniques on a “fit and forget” basis. This means there is no longer requirement for the time consuming costly step tests and recalibration of the previous multi-variable control models as the Dynamic Solutions framework provides the capability to tune the multi-variable controller from the reconciled dynamic model. It is an example where process modeling and process control is now becoming cohesive to the benefit of process industries and the users.

The process-modeling journey is illustrated below.

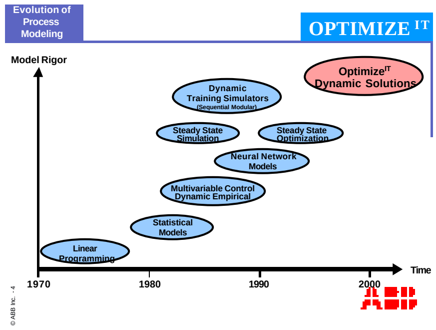


Figure 3 –

In every case, the suppliers of process control equipment such as ABB have followed the lead provided by the universities, with a gap between the research and the first commercial products.

It is interesting to reflect that while twenty years ago many of the large process companies had large leading edge process control groups that were able to develop and prototype university research in industry, very few companies now retain such groups. Increasingly it is the obligation of suppliers such as ABB, to be the direct translators of university research into industrial products. These companies are now the first tier suppliers for both hardware and technology to the process industries.

1.3 Industrial^{IT}

Over the past 30 years signal processing has evolved from analogue signals, initially pneumatic and then electronic to totally digital processing. The journey is illustrated in the figure below.

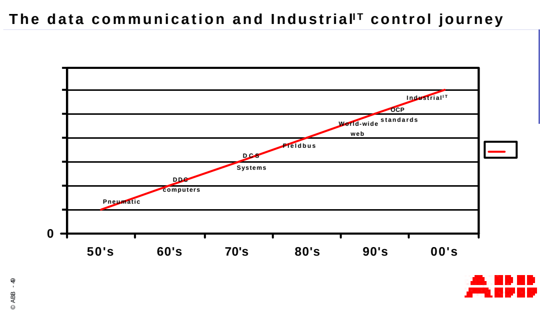


Figure 4 – The data communication and Industrial^{IT} control journey

On reflection, and not surprisingly, the key driver of this whole evolution has been the digital computer. It is only forty years ago that the majority of process plants used pneumatic instrumentation. While in its own way very clever, and very simple, it was clearly very difficult to transfer data from these instruments to any form of central location. In fact the best that could be done was the operators manual recording information that may be manually analysed by others. Rotating pneumatic scanning valves that converted pneumatic signals into digital signals were developed but these were restricted to a very few applications.

It was in the late sixties that the first direct use of computers to control process plants was developed by ICI in the UK and Monsanto in the US. Unfortunately all the instruments and all the valves were pneumatic, hence numerous analogue to digital and digital to analogue converters had to be installed to make this possible. Nonetheless the principle was established. This rapidly took off through the seventies and computer controls were installed in many large plants, primarily to allow concepts such as advanced control and optimization. For anybody who was working in that era a real challenge was the need to communicate with numerous different standards of interfaces with pneumatics, electronics and other people's instruments.

This led to an industry demand for a concept, which eventually became known as Fieldbus. The concept of Fieldbus was that anybody's instruments could communicate with anybody's computers over a single standard interface. It is interesting to note that the author first heard of Fieldbus in the late seventies, and it is only now that it is becoming the standard demanded by the industry. A gap of almost 30 years! The evolution of this has been long and torturous, and it may well be suspected that it was not in everybody's interests to make it succeed.

In the early nineties the concept of the Internet and the worldwide web arose. This came from a totally different direction, and was developed for the totally different need of transferring huge amounts of data across the world using existing spare computer capacity. It had nothing like the standards effort of neither Fieldbus nor the numerous committees that made it possible. Nonetheless it rapidly gained acceptance as a worldwide standard because of its ease of use, availability and effective low cost. As a consequence of this, suppliers are now developing the web for communication between instruments and computers etc, and the next Internet Standard, will incorporate real time processing features and will probably replace some components of Fieldbus.

In the nineties, ABB took a fundamental review of the whole question of information flow both between plants and business systems and between components across plants. The result was the concept of Industrial^{IT} (Reference 8).

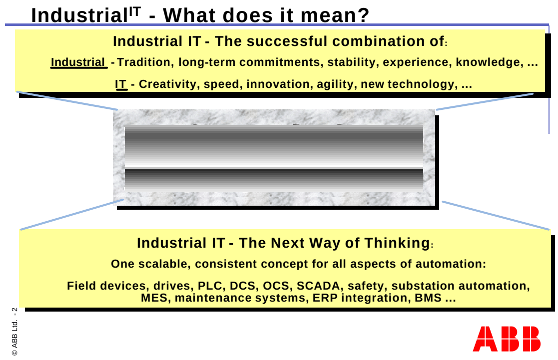


Figure 5 – Industrial^{IT} –What does it mean?

To put the significance of Industrial^{IT} into context is probably appropriate to remind people that there was a time before Windows Office when letters were typed on typewriters and duplicates used carbon paper. That is probably no more than twenty years ago. Within that time typewriters have disappeared, carbon paper is a thing for a museum, and Microsoft Office has been the standard for all offices in the world. ABB believes that Industrial^{IT} will become the standard for communication in the industrial world. The key and unique feature of Industrial^{IT} is to recognize that every object in the plant has information associated with it that ABB call aspects. Consider a typical life science sample, which is an **object**, illustrated below.

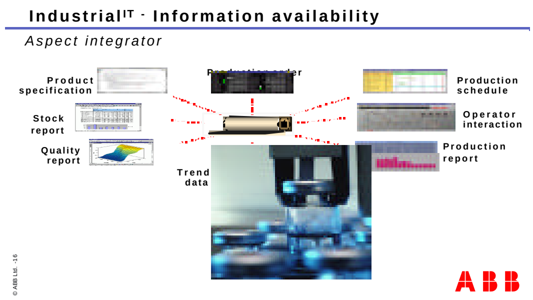


Figure 6 – Industrial^{IT} – Information availability

Each object has associated with it many **aspects** of information. This is all the information that is associated with that product. Quite deliberately, this is all made available to the users in the industry standard formats as illustrated below.

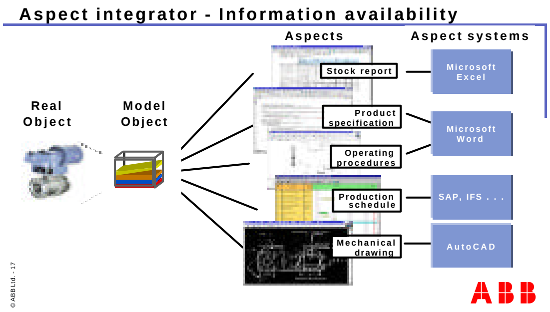


Figure 7 - Aspect Integrator – Information availability

The result from the user is a system that is cheaper to install, where documentation is always up to date, and which allows transparency of information at all levels. It is this transparency and instant access to information, plus the potential that it is dynamically reconciled, that makes this system potentially so powerful for tomorrow's processes.

Embedded within all the modules is the knowledge that runs all the assets. The basic building block is an asset and every asset has data and information attached to it and by converting that data into wisdom one is able to add value and save money at every stage of the asset life.

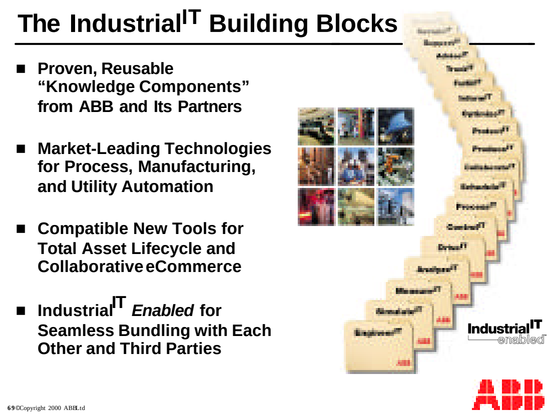


Figure 8 – The Industrial^IT Building Blocks

This is a trend recognized by ABB and described as Real-Time Enterprise Integration.

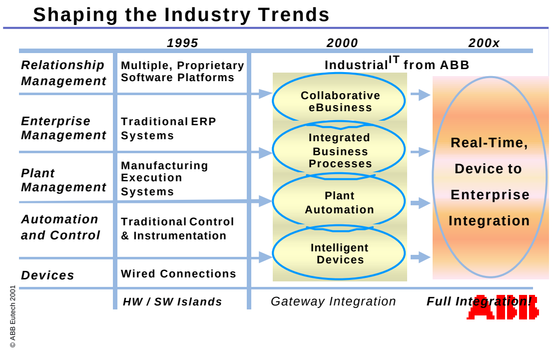


Figure 9 – Shaping the Industry Trends

The challenge facing the industry is to exploit all this technology against a background of restrictions in skill base.

1.4 Where are we Now?

All plants have computer control, nobody would now consider otherwise. The hardware is miniaturised and moving to the fact that in the future a DCS system will not be much bigger than a desktop computer.

All the basics of process control are now standard options. Control loops offer failsafe, two out of three voting, plus all the advanced options as a menu to those who run the systems.

1.5 Cohesive Control

The opportunity is now right for all the advanced control, process modelling and Industrial^IT to integrated into a totally seamless offer, which the author has termed **Cohesive Control**. In this world: -

- Model based predictive control is available and adopted for all manufacturing processes from slow processes through to very fast processes

- IndustrialIT makes all the accurate real time information available to the control / optimisation continuously

- Existing computer / communication speed allows advanced real time control of the electrical supply which represents an additional degree of freedom.

- Rigorous dynamic models may be prepared quickly and solved at ever increasing speeds as Moore's law continues to survive and computer speeds keep increasing. Ownership, use and exploitation will become the real core of an operator's competitive advantage.

- Real time control of sustainability becomes a reality

With these drivers the author suggests the concept of Cohesive Control illustrated below.

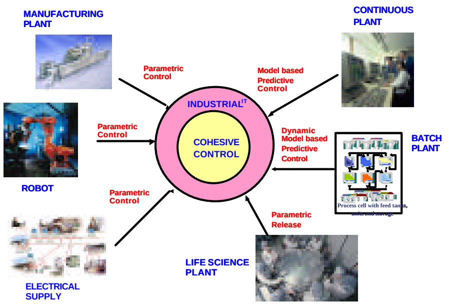


Figure 10 – Cohesive Control

1.6 Cohesive Control in the Future

In this concept the users have available and apply the same tools and techniques of advanced control and optimisation irrespective of the type of process being managed. The advantages are many and include: -

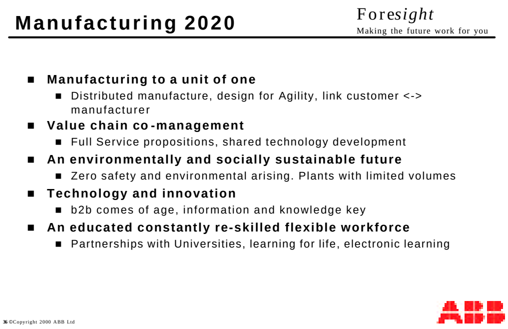
- No longer distinguishing between batch and continuous, manufacturing or life science

- Adopting best practice from one industry and rapidly spreading to other industries

- Increasing productivity at all stages from design through to operations from a reduced skill pool

1.7 Tomorrows Process Industries

One lesson of the last 30 years is that process control embodies and reflects the knowledge of the manufacturing process. The real know-how and IPR is in the software that controls and models the process. Predicting the future of process control one has to predict the future of process manufacturing and the potential synergies. Fortunately others such as the UK Foresight initiative in the UK have defined a future view, which is summarised below.



These views are supportive of the domain specific views expressed in the Competitiveness of the UK Process Industries published in 2001 (Reference 10), Processing the Future published by the DTI in 1998 (Reference 11) and the authors book on Benchmarking Process Manufacturing published in 1999 (Reference 12).
These all suggest that tomorrow's processes will be "agile" and designed to exploit the full potential of process control. That includes cohesive control of: -

- The actual chemical processes
- The energy sources such as electricity
- Safety, health and environment
- Sustainability
- Management of the maintenance
- Operation of the supply chain

All the control will be in the context of multi-variable statistical process control, as the products will go straight to the customers without any laboratory testing or final product storage.

The web is pervasive and it will become the route of communication with all the control schemes at both the plant and the supply chain level. Users will expect the same flexibility and freedom of use that exists on the web booking travel fares today. It is quite conceivable that the control scheme will sit remote from the actual operation or maybe on a shared basis with several plants and one can envisage the operation of plants to be very similar to the operation of the stock market that one sees on the TV screens every morning. The analyst or the operator purchase the raw materials, decide which plant they go to in the world, the plant produces it and the operator then dispatches it to various users. On-line trading will make that more possible and off it goes.

The prime driver is the market is the supply chain. The final customers requires just in time delivery in full of products at all time with zero defects. Manufacture to a unit of one is the key flexibility driver. One interpretation is that the chemical plant has to be designed to be able to produce a batch size equal to the smallest order size, even to the case where the order size may be one drum of chemicals. This demands manufacturing processes with the following characteristics.

- Design for minimum inherent volume and capacity.
- Build quality into the whole process from beginning to end such that Six Sigma performance is achievable.
- Smart sensors
- Totally accurate mathematical models
- Application of multi-variable statistical process control to monitor the operational process.
- Direct link between the real time plant and the business systems.

Given what has been said earlier, the ability to provide a totally accurate dynamic model will be possible with developments such Optimize^{IT} – Dynamic Solutions.

To meet these requirements will demand a wider spectrum of manufacturing processes from the ever-larger continuous plants at the source of feedstock through to the distributed, intensified and small plants that work on a made to order basis at the point of use. Throughout the spectrum the requirements will be for "smart operations" where the control, and the knowledge, must be used to match the process output and quality to an ever more variable demand. This is Cohesive Control.

This presents a very interesting research challenge for the process control community. ABB are already researching all these areas as a leading first tier supplier.

2. CONCLUSION

Tomorrow's processes will be agile. The technology exists to develop, control and manage these processes. It will be a form of cohesive control that not only applies to the processes but also applies to the electrical/energy supplies and to the whole supply chain. This is an interesting challenge, which ABB is vigorously taking on at this time based on its unique Industrial^{IT} platform. Embedded within all the modules is the knowledge that runs all the assets. The basic building block is an asset and every asset has data and information attached to it and by converting that data into wisdom one is able to add value and save money at every stage of the asset life. This future vision probably says that most companies do not have offices, that all the finance and HR is done automatically, that many of the future plants are manless and are distributed adjacent to the customers to save distribution costs in the supply chain. Ultimately they will be powered over the "grid" which is the next generation of high-powered access. The principle of the grid is that any user should have access to computing power of unlimited computing when and where they want it just like electricity today. This leads to the longer-term vision of global control that has some very exciting possibilities and some interesting implications

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