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A Framework and Survey of Advanced Process Control Economic Evaluation

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Abstract - Stabilizing the process operation is a major goal of commercial advanced control of processes (APC) programs. The advantages of implementing new APC technologies into a process must be measured economically so as to justify the expense involved. Previously, techniques for economic evaluation were created that connected changes in important regulated process variables to measures of economic performance. In order to gather industry norms and recommendations, an investigation into the current method of assessing APC's economic performance was conducted. The purpose of the questionnaire was to determine methodologies for estimating economic performance and to assess the impact of economic performance on the managerial process. The questionnaire was made available in two somewhat different versions: one for experts working for production firms (also known as APC users) and another for specialists working for APC structure suppliers (sometimes called APC providers). Process control engineers, managers, and creators of control technology were all a part of the target group. This study examines these techniques and applies them to an economic evaluation approach for APC projects. 125 APC specialists from different industries were undertaken for evaluation regarding ROI of control of processes. The findings provide details on the evaluation of the financial advantages of sophisticated process control.

Keyword - Advanced Process Control (APC); Fuzzy Logic Control; Economic Evaluation; Managerial Process.

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INTRODUCTION

The commercialization of a new APC (Advanced Process Control) innovation and its transition from the research and development stage to widespread implementation are made easier by the APC schemes' economic appraisal. If the consequences of control systems for processes and their economic benefits are clearly correlated, then the control system's investment cost may be compared directly to the advantages of creating a business case (Bauer and Craig, 2008). Therefore, financial analysis is essential to the advancement of control technology innovations and serves as the foundation for the primary business reasons of process control. These company objectives include dependability, safety and environmental regulations, reduced variability, which moves process variables closer to their ideal values, and customer requirements (Edger, 2004). Over 6000 APC applications were predicted to exist worldwide in a recent commercial publication, and it has been gradually increasing over the past few years (Canney, 2005).

APC has been grouped under various headings. Model Predictive Control (MPC) is now a widely used design in APC. Advanced Process Control and Model Predictive Control are hence interchangeable in the control engineering community (Asawachatroj and Banjerdpongchai, 2012). The use of other controls such as Fuzzy logic control (FLC), Nonlinear and Adaptable Controllers, Neural Networks (NN), Predictive Function Control (PFC), Active Rejection of Disturbances Control (ADRC), Process-Model Based Control (PMBC), Generic Models Control (GMC), and Internal Model Control (IMC) is still possible thanks to modern Computer Technology (Rhinehart et al., 2011). These controllers are also regarded as APC (Advanced Process Control) technology.

Choosing the best instrument from the knowledge of process control is a crucial stage in making the investment decision for the IACS project, which must be in line with corporate strategy. Heavy industries have been utilizing APC, particularly MPC, for more than 20 years. More than 6,000 APC applications have reportedly been submitted globally during the last five years, and that number is continuing to rise (Canney, 2005). It's crucial to decide whether APC ought to be implemented on top of the DCS platform. This is due to the fact that the initial expenditure of an APC can range from a few hundred thousand dollars to millions of dollars. A crucial tool for calculating the project's cost and benefits is economic assessment. After that, use financial

analysis to demonstrate the value of the business drivers for process control.

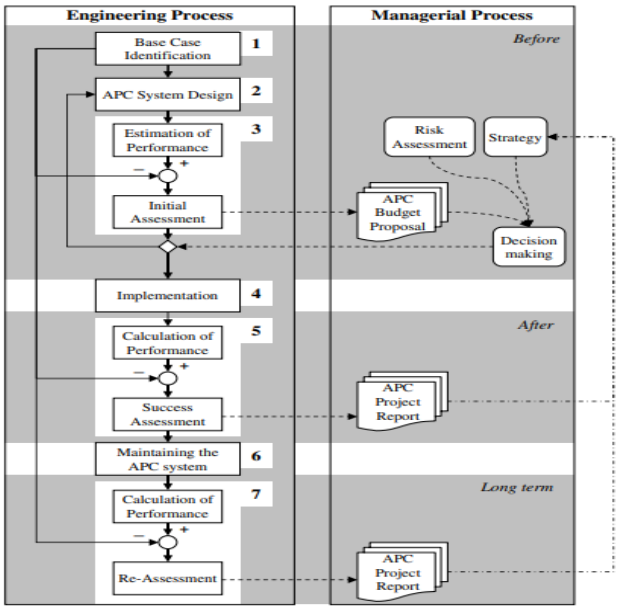

Fig.1: APC's technical and managerial structure for evaluating economic performance.

The APC phase of a project is a challenge for process control engineers today (Canney, 2005); with proper application, the system operates at maximum proficiency. The efficiency of the APC system deteriorates with time as a result of variations in the operational environment and equipment process, and ultimately the controller may even be turned off. Advertised payback periods for APC projects range from three to nine months, however in many cases, the maximum effectiveness wears off sooner and the money invested yields less than expected returns.

In this research, a paradigm for evaluating the financial outcomes of APC initiatives is introduced and discussed (see Fig. 1). At a business workshop, the framework's fundamental version was presented and discussed (Bauer and Craig, 2008). The framework was subsequently enhanced to include the assessment processes throughout the life phase of APC projects by outlining concurrent management and engineering procedures that are commonly implemented in manufacturing organizations. The enlarged framework is used to organize this essay. As seen in Fig. 1, the stages for the economic evaluation can be divided into three major blocks. The cost and benefit estimation of a fresh endeavor prior to implementation is covered in the first block. The second block describes how to calculate efficiency and do an economic assessment after the system has been established and when operational info from the system's recent implementation is available.

The final section of the evaluation examines accomplishment following a period of time. After this time, the working environment will probably have changed, which could have an impact on the controller's performance. APC system maintenance and the final evaluation stage may need to be conducted multiple times to ensure that the regulator is still providing the required performance. The survey including benefit estimation, computation, and reporting was created to be sent among APC industry specialists. Sixty-six interviewees shared details about their organizations' economic assessments.

Historical progression

Since the earliest installation of such systems, process control engineers have been concerned with the economic evaluation of such systems. Therefore, industry authors who deal with the topic on a daily basis report the initial applications. The subject matter is still quite interesting, according to recent reviews (Latour, 2006). Though extremely relevant and useful in practice, many of the presented methods lack a theoretical basis and heavily rely on simplistic assumptions.

The development of computing devices for control of processes in the beginning of the 1950s (Stout, and Williams, 1995) was the first significant technological advance that sparked a debate regarding economic efficiency: when is it worthwhile to invest in a computerized system of control? Numerous case studies detailed sizes and processes for which computer oversight may have a large economic benefit in addition to reporting successful installations and benefits realized through control of computer (Eliot, T. Q., & Longmire, 1962; Madigan, 1963). Because of this, Williams saw a linear rise in the 1960s in the usage of management of processes software at chemicals and petroleum companies (Williams, 1965).

When it became clear that computer control could truly enhance profitability in the 1970s, the majority of manufacturing enterprises shifted to the latest computer technology. Technology has occasionally been installed merely for its own sake (King, 1992). The availability of operating data, enhanced process knowledge, and alert management were mentioned as examples of hidden or indirect advantages of computer control (Jakubik et al., 1964). Dynamic control techniques were now covered in conjunction with steady-state design (Chintapalli and Douglas, 1975; Cutler and Perry, 1983). Control systems suppliers, including Setpoint Inc. (Latour, 1976), Profimatics Inc. (Stout and RP, 1976), The Foxboro Company (Bernard et al., 1978), and Honeywell (Su, 2004), were primarily responsible regarding the advancement of economic appraisal in the decades between 1970 and 1980 as a driver and rationale for their products. A sounder theoretical foundation was established for the variance reduction's financial repercussions as determined by performance functions (Zhou and Forbes, 2003; Muske, 2003). Recently, Xu et al. (2007) created a method for evaluating the economic performance of MPC.

RESEARCH METHODOLOGY

A questionnaire was used to perform the survey on the economic assessment. The questionnaire was offered in two somewhat different forms: one for subject matter experts working for manufacturers (also known as APC users) and another for subject matter experts working for APC system providers (also known as APC suppliers). The target audience included control technology developers as well as process supervision engineers and managers. The survey was completed by 65 APC specialists, 35 APC users, and 25 APC suppliers (125 respondants).

The majority of manufacturing companies operate in the petroleum refining, petrochemical, chemical, and minerals processing industries; however, APC suppliers often provide to a range of industries with their products and services. We also have the oil and gas sector, cement, food, glass, and steel manufacturing.

Design of Questionnare

The questionnaire's material followed the framework in terms of organization. The first section included all the frameworks related to the Engineering Process. In which all the strategies and their evaluation included, like minimal case identification, APC system design, estimation of performance, profitable factors and cost types, etc.

In the second section, Framework of Managerial process discussed. The managerial process is covered with questions regarding reporting, decision-making, and budgeting, while the engineering process and cost and benefit estimation are covered in it.

The respondents were questioned on the precision, significance, and satisfaction of the existing Estimation procedure in place in addition to regarding potential future developments.

RESULTS

Framework of Engineering Process

Continuous processes are the main emphasis of both the survey and the majority of APC projects. 91% of survey participants work with continuous processes. Given that the refining, petrochemical, and chemical industries have considerably fewer batch operations, cost/benefit analyses of batch operations are performed and reported less frequently. However, the majority of the techniques discussed here can be used for both batches and continuous operations when the temporal trend is being observed.

A minimal case identification

APC experts were questioned regarding the initial case performance and benefits in the questionnaire. The choice of the suitable process variables from which variation is computed is then crucial for base case identification. The following variables were included in the study:

- Important product characteristics.
- Significantly altered variables.
- Parameters for the material and energy balance.
- Limiting factors.

APC system design

The conceptualization of the latest system of control, as shown in Fig. 1, comes next after the basic case has been developed. The decision about the control mechanism is perhaps the most crucial one for the design of the APC system.

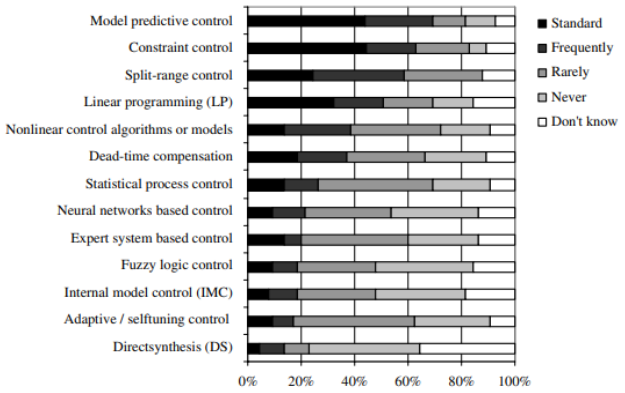

Fig.2: APC techniques used in industry: survey findings

The respondents to the study Were questioned about the frequency of use of APC methods in business. The outcomes are displayed in Fig. 2. Some respondents also mentioned inferential control, combustion lambda control, and strong MPC technology as additional APC techniques. The findings demonstrate the advancement of predictive modeling in the process industries. Over two of the people surveyed use it often or as a standard tool. In the ongoing processing sectors, constraint control and split-range management are also often employed. Computational intelligence methods such as neural nets and fuzzy logic are among the less-used strategies, while some claim they can yield large financial gains.

Estimation of performance

The estimated and base case efficiency of the redesigned APC system are contrasted. Using performance functions, it is feasible to calculate the new controller's average performance. The operating point can be moved nearer to a limit xL by $\Delta\mu$ in the scenario of a constrained performance function. By comparing the average performance prior to the new system to the performance anticipated from the revised control strategy P after av, it is possible to quantify the improvement brought on by the control

system upgrade. This enhancement can be represented as a profit index calculated from the variation reduction brought about by the new system and a minimal possible variance estimate, and the anticipated average perform.

Profitable factors and cost type

The questionnaire asked APC consumers and vendors to list the top three factors that contribute to the advantages that come from increased process control. The most often mentioned criteria are listed in Fig. 3. A definite pattern can be seen despite the tiny sample size.

From the obtained results it can be clearly seen that the throughout increase is about 68%-70%, according to the statements of suppliers as well as users. On the other hand, suppliers stated that the process stability improvement is less than that of 50%. Reduction in energy consumption shows 65% of the poll value. There is an optimum increase in the yield of the product and quality giveaway reduction in the products as shown in the Fig.3. The amount of labor needed for the setup from the prospective APC user and the provider is the most significant cost component. The management upgrade to the software has a bigger influence on the execution expense as the control hardware upgrade because the majority of the APC solutions are software-based.

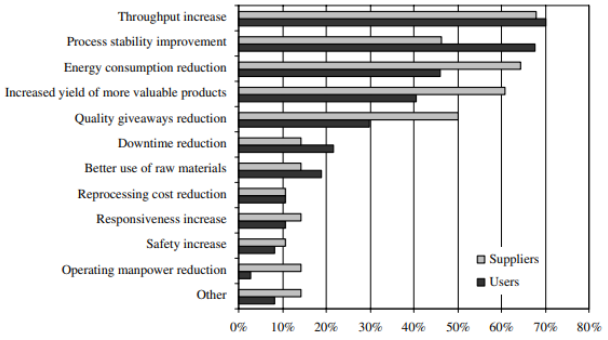

Fig.3: Survey results of main profitable factors

Upgrades to control systems frequently involve more intricate equipment and cost more money. Only 35% of the survey participants named maintenance as one of the top three cost drivers. This can imply that system upkeep receives insufficient attention.

The process of execution and performance evaluation

APC solutions are listed in Fig. 4 and are organized according to the understanding that survey participants have of them. The three most popular APC toolboxes are Aspentech's DMCplus, Matrikon's ProcessACT, and Honeywell's Profit Suite. According to this study of 39 APC users, AspenOne is the most often applied the typical APC solutions. Notably, more than 51% of those using it have developed their own APC software and employ internal expertise to develop new control technology. According to the study, practically All APC projects completed by APC suppliers have a duration of four months to a year. The majority of APC customers with in-house competence, however, complete their programs in no more than three months, with only a third of their projects lasting longer than a year.

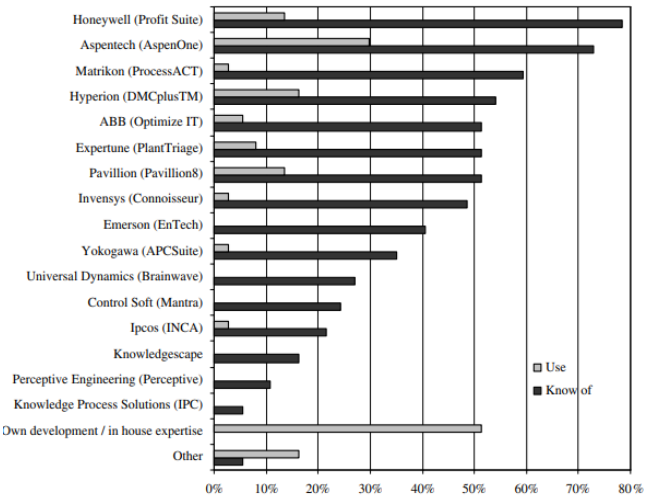

Fig.4: Results of the survey ranking APC solutions by popularity.

APC professionals were questioned in the poll regarding the evaluation of the new system's advantages following its deployment. The effectiveness or lack thereof of the new APC system is determined by shifting from both the previous and the current control systems, according to 82% of APC vendors along with more over 53% of APC users. When the old and new systems are properly switched on, a assurance level should appear that indicates how trustworthy the outcome of improved control is.

Maintenance of APC system

The performance of practically all APC systems would degrade over time if left unattended, which is a technological flaw. Therefore, the upkeep of the APC device is necessary to guarantee sustained performance. The survey has cleared it that, 12% of the participants said that the inability to handle maintenance was the reason process automation was not being used to its full potential. Control loop performance assessment has changed to concentrate maintenance resources on the lowest-performing loops. On what basis do you evaluate the performance of your loops? were the questions posed to the respondents of the online poll. The majority of users (about 71%) regularly assess either online or in their loops (23%), daily (20%), weekly (10%) or monthly (18%). Loop monitoring is a crucial and well-liked stage in keeping an eye on and sustaining the APC system.

Framework of Managerial Process

The framework in Fig. 1 illustrates the managerial instruments and techniques that are utilized with regard to the APC system as an asset. The APC system must be monitored and evaluated using reports at various points during the engineering process, including before and after installation reports and a long-term report. The decision to invest in an innovative control technology influenced by the favorable or negative reports. The decision is typically supported by a risk analysis.

The Reporting

The methodology for evaluating economic performance considers three reports that are typically produced in a commercial environment to evaluate the success or shortcomings of an APC Programme. An expense is supported by a budget plan before it is put into action. Project reports are turned in both at the start of the project and after a certain amount of time has passed in order to monitor performance and assess the success or failure of the APC project.

APC experts were asked about their organization's requirements for APC reporting in the poll. 82% of those who responded to the poll said that whether the investment is being justified in monetary terms or as an operational parameter such as output or a quality characteristic, a quantitative report must be produced before the implementation. 76% of respondents said that no investment is made without managerial clearance, and the other 26% said that control expenditures below a threshold didn't need permission at all.

Assessment of Risk

It is imperative to consider risk factors for project failure and excessive costs in any undertaking. There are risks involved in a number of the implementation components of an innovative APC system. From a managerial perspective, user acceptability and management support are two significant risk variables impacting the project's outcome. Only 17% of respondents considered that management support was more crucial to the success of an APC project, compared to 58% who felt that user acceptability was more crucial.

Making decisions and development of plan

According to survey replies, among the APC specialists, half choose a control system with which they are already familiar, because they have had positive experiences with it on processes that are comparable to their own. A further 26% of respondents said they abide by advice from APC vendors. A pilot project is frequently conducted after this recommendation to confirm its efficacy and advantages. 7% of the respondents stated that working with universities was a factor, especially when it came to developing financial models as well as functions.

CONCLUSION

With regard to advanced process control (APC) systems, the study has looked at a number of approaches, measures, and factors that are critical to evaluating the viability and advantages of applying APC in manufacturing procedures. Although process management technology has grown over the past few decades, evaluation methods for the financial gain from sophisticated control solutions seem to have stayed the same. The benefit estimating techniques for decreasing variance that were first presented in the early 1970s are being used and documented today. This study provided an overview of the economic evaluation issues in the context of a structure that included evaluation processes throughout an APC project's life cycle. Taking into account many aspects like startup costs, ongoing expenses, efficiency gains, and risk reduction, decision-makers can make better-informed decisions on the adoption of APC technology. The outcomes of survey on APC's economic performance evaluation paint a picture of the most advanced assessment techniques used by businesses today. In this paper economic assessment methodologies and case studies highlights the variety of approaches and resources available for determining the financial impact of APC systems. It is becoming more and more important to comprehend the economic consequences of APC systems as firms use them to improve product quality, lower energy usage, and increase process efficiency. The findings show that the majority of APC users and suppliers perform cost/benefit analyses and are obligated to present the results to organization. The significance of a thorough framework that incorporates the technical, financial, and operational facets of APC evaluation is one important lesson to be learned from this study.

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