Potential Applications of Advanced Control System Strategies in a Process industry—A Review

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Abstract Present paper attempts to review the applications of advanced control strategies based on artificial intelligence techniques and its hybrid counterparts applicable in process industry. This chemical process industry may be textile, paper, water purification plant, sugar mill, leather, steel, or any sub-process which may be common in all these industries. It covers an exhaustive literature review.

Keywords Process control · Control system · Controller tuning · Time delayed process

1 Introduction

The process modeling involves the development of dynamic mathematic models with state space forms describing the thermal state in the heated and cooled objects. Dynamic model-based optimal control strategies for both batch and continuous thermal processes in terms of the maximum principle, dynamic programming, heuristic search, etc. are also proposed in this study. The target of the development of optimal control for the heating processes is to provide the optimal heating patterns based on the given criteria and constraints associated with dynamic models and others. A complete hierarchical computer control structure for heating processes is proposed [1]. Nixon discussed recent advances in the use of programmable logic controllers for batch house control systems [2]. Jaggers explored that more accurate sensors make possible tighter control loops [3]. Taniguchi et al., applied advanced technology for cold strip mill installed in Japan that improved gage accuracy. The specifications and features of the mill are set forth, and the gage control system is examined in more detail [4] (Table 1).

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Table 1 Literature review

Sr. no	Authors	Year	Technology	Application
1	S. W. Nixon	1988	PLC	Batch house control systems
2	T. Taniguchi et al	1989	Advanced gage control system	Cold strip mill
3	C. Constantinescu et al	1990	DCS	Industrial applications
4	P. P. Aslin	1992	ACS	pH control in sugar mill
5	E. M. Heaven	1993	Parametric techniques	Paper machine
6	G Lightbody et al	1994	System identification techniques	Polymerization reactor
7	G. Rigler, et al	1994	Simulation and control	Multiple stand hot strip mill
8	Zhang Qiping et al	2003	APC	Industrial application
9	H. Ren-Chu et al	2013	MVC controller design	Ammonia synthesis process
10	P. K. Juneja et al	2013	MPC strategy	Lime kiln process
11	P. K. Juneja, et al	2018	Modeling and simulation	Paper machine headbox
12	P. K. Juneja et al	2020	Modeling, control and instrumentation	Review on lime kiln process

Constantinescu et al., presented the hierarchical structure of an integrated control and management system for industrial applications. Its main levels are: distributed process control, process operations support and plant management. This structure has been specialized in the case of a cement plant. The architecture of a gracefully degrading advanced control station is given which supports the process operations in the case of medium size applications, such as cement factories. Result of the global and local repair actions, effect of the spare processing elements and influence of different types of faults have been emphasized. The main advantages of the presented advanced control station are that only the redundancy manager and the application software have been especially designed. This has led to a low cost implementation of the station [5].

Lewis discussed a practical process industry problem of considerable difficulty and defeated conventional approaches [6]. The chemical company Du Pont uses advanced process control to improve operability of plants. This enhances safety, protecting people and the environment, and defines product quality within narrow limits. It reduces costs and increases profits. It is shown that the use of advanced process control enhances safety and increases efficiency [7]. Aslin presented advanced control process for pH control in a sugar industry [8]. Jones, discussed the application of dynamic simulators in industry. The use of training simulators is quite widespread within certain process industry sectors such as refining,

petrochemical and oil and gas. Due to advances in technology and a wider awareness of the benefits these simulators are increasingly used for engineering and operations purposes. In the future the distinction between training and engineering simulators can be expected to be less clear. It is thought that soon a single tool will be available to enable a simulator to be used from conceptual design through to operations support [9]. Gough shown that the use of orthogonal filters allows transfer function identification [10]. Vachtsevanos et al., presented a new technique to optimize the slasher control parameters [11].

Heaven et al., examined some of the traditional parametric identification techniques [12]. Cameron presented the results of field applications in mercury reclaim and sulfur recovery [13]. Model and rule-based controllers can provide adaptive feature within a robust controller design framework [14].

Lightbody et al., proposed to utilize model-based approaches to improve the control performance of an industrial polymerization reactor. This involves the development of a process model using system identification techniques, the simulation of the plant within the Simulink environment to allow for the design and validation of control strategies. From these studies a Smith predictor was implemented to significantly improve the polymer viscosity control. Finally, a hardware platform is developed to facilitate the implementation of sophisticated algorithms such as recursive least squares that could not be accommodated on the present DCS [15]. Rigler et al., attempted the simulation and control of a multiple stand hot strip mill [16]. Arruda et al., proposed integrating different software resources with an application example of an oil industry [17]. Graebe Goodwin et al., described three different central strategies that were implemented and evaluated viz. a dithering controller, a linear cascade controller, and a nonlinear cascade controller [18]. Wilkinson et al., reviewed chronologically the status of fuzzy logic from the start to the present scenario [19]. Zhang Qiping et al., applied APC technique on an industrial process and shown that APC technique is capable of mastering and improving the key process targets [20]. Xiaoming Jin et al., performed advanced process control techniques [21]. Li-hong Dai et al., applied a method based on human machine intelligence [22]. Ren-Chu et al., designed six MVC controllers for the ammonia synthesis process. The final industrial application resulted in good control performance and economic benefit [23]. Juneja et al., applied MPC strategy on a lime kiln process. The lime kiln model is perturbed and the responses achieved are compared for controller designed based on MPC strategy [24]. Satisfactory system performances have been achieved by implementing MPC on real plant [25]. Juneja et al., showed that FOPDT model resembles consistency parameter [26, 27]. MOR and MIMO control system analysis techniques are depicted with the aid of flow chart [28, 29]. Modeling and control features of lime kiln process are attempted [30].

Yunhui Luo et al. [31] gives an improved version for the identification of FOPDT model when the response data is very less. So to approximate the step responses a B-spline series expansion are used which in turn provide more operative interpolation values for modeling computation. Least squares method diminishes the eccentricity of response between identified model and actual process by adjusting the error weight coefficients. Anindo Roy et al., [32] used the solidity framework of Hermite-Biehler

theorem for FOPDT process model. The resultant simulation results illustrates that this frame work can be efficiently used for the synthesis of PID controller of the FOPDT model. The proposed method gives comparably more superior results over traditional PID tuning approaches.

Qiang Bi et al. [33] projected a robust identification technique that has been derived from a step test. This method gives improved identification result then that of the prevailing method under step testing and can be easily applied to PID auto tuning. IMC-based control system displays better control action in comparison to Ziegler Nichol's based control system [34].

2 Conclusion

An attempt has been done to review the applications of advanced control strategies which are applicable in process industry. It covers many control strategies viz. programmable logic control, distributed control system, system identification, multivariable control system, modeling and simulation, model predictive control, etc. And many application areas such as, cold strip mill, sugar mill, paper machine head box, polymerization reactor, multiple stand hot strip mill, ammonia synthesis process, limekiln process.

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