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Model Based Predictive PID Control System for Chemical plant

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Abstract— The chemical plant is the most important part of process control application which includes complicated physical and chemical reaction processes with large ratio of chemicals and its properties varies from application to application. Considering the need of advanced process control in chemical industry, this project presents the application of support vector machine modeling and generalized predictive control PID control algorithm to the conventional chemical production. The main control system structure includes three control loops as the concentration control loop, the burning zone control loop and the back-end of level control loop. Based on the analysis of conventional PID and generalized predictive control algorithm, the performance index of generalized predictive control algorithm is restructured into PID form. By analysis of the simulation data, the nonlinear regression model based on SVM is introduced. The control algorithm using SVM model is simulated in two cases to derive the responses of system compared with the ordinary PID control algorithm. In the following next simulation results show the effectiveness of the control and modeling scheme with better response time and small level deviation.

Keywords—PID; MATLAB; SVM; Model predictive control

I. INTRODUCTION

RECENTLY, the permanent magnet synchronous motors (PMSMs), which have advantages such as high efficiency and low inertia, have been extensively utilized in ac motor drive applications along with the rapid development in power electronics and especially digital signal processors (DSPs) that can quickly perform advanced vector control algorithms. To control PMSM, linear control schemes, e.g., proportional-integral (PI) controller and linear-quadratic regulator have been widely applied due to their relatively simple implementation [1]–[4].

Unfortunately, PMSM servo system is a nonlinear system with unavoidable and unmeasured disturbances, as well as parameter variations. Moreover, in practical applications, PMSM systems are always confronted with various disturbances that may be generated internally, e.g., friction force and unmodeled dynamics, or externally, e.g., load torque. As a result, it is very difficult for linear control schemes to achieve high performance.

Therefore, nonlinear control methods can become an alternative solution to accurately track the reference trajectory of PMSM. In recent years, various nonlinear control algorithms have been presented, such as adaptive control [5], [6], robust control [7], back stepping control [8], feedback linearization control [9], direct torque control [10]–[12], and intelligent control [13].

In particular, sliding mode control (SMC) [14], [15] is one of the most attractive methods that can precisely regulate PMSM. It is well known that the most salient advantage of this technique is robustness to system uncertainties and disturbances. However, its implementation suffers from a chattering problem which occurs when the control input switches is continuously across the boundary. This is undesirable because it involves high control activity and may excite high-frequency dynamics [16].

To suppress the chattering, various methods such as SMC with boundary layer [16] and SMC with sliding sector [17] have been proposed. The basic idea behind these works is to smooth the control action across the sliding surface while preserving the traditional SMC law. To improve the system response of the traditional SMC, in [18], a two-phase SMC law that incorporates the distance of the system state from the sliding surface into the controller design was presented. The principle of this method is to include an extra distance dependent on variable term that helps reduce the hitting time because the switching control action in SMC is usually not strong enough to attenuate chattering. However, chattering may still occur under certain operating conditions.

II. PID CONTROLLER

A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs.

Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral value may prevent the system from reaching its target value due to the control action.

The standard PID and Generalized Predictive Control (GPC) have been used to regulate the process fluid temperature (cold) by means of the flow rate of hot fluid (control signal). The actuator is a solenoid valve. It will be shown that the GPC offers better disturbance robustness and better set point tracking characteristics. It is important to observe that the proposed GPC scheme can be advantageously implemented by means of the so-called “predictive PID” control law, which is characterized by the same performance without employing ant windup device and specialized software.

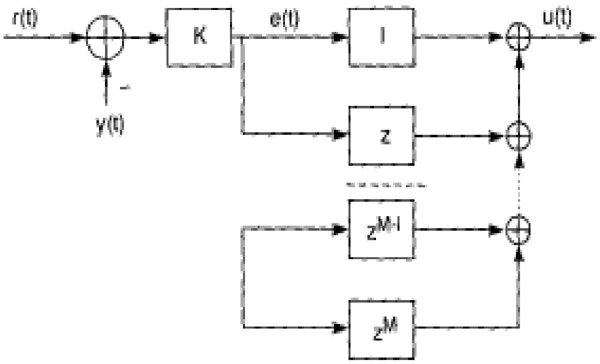
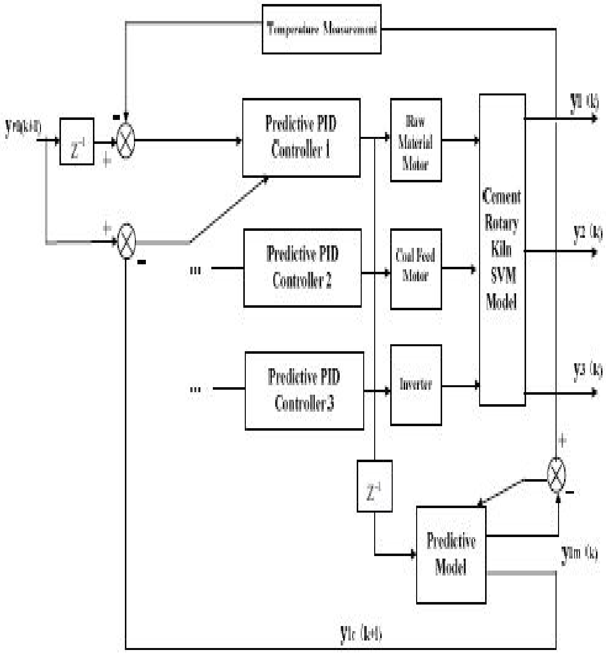


Fig. 1 *Outline of predictive PID controller*

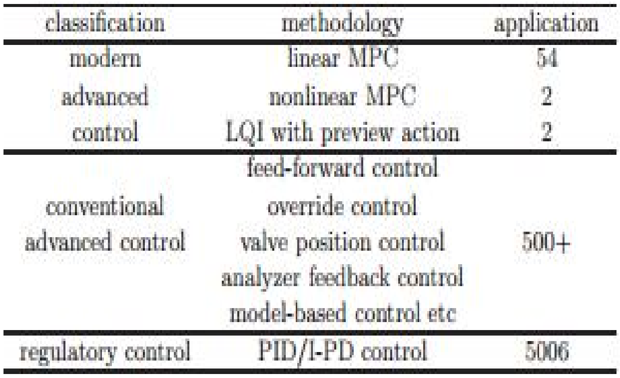
A new extended model of a heat exchanger and a comparison between two temperature control methodologies, standard PID and Predictive Control, are considered. The proposed model is one of the most general which has been used for control purposes. The PID and Predictive Control have been designed by means of a reduced system representation obtained both by identification and model reduction techniques applied to the extended model. The two control methodologies are tested by using a higher order model which can be considered as the real system. The simulation results have shown better characteristics concerning both set point tracking and disturbance robustness for Predictive Control.

III. MODEL PREDICTIVE CONTROL

Model predictive control (MPC) is an advanced method of process control that has been in use in the process industries in chemical plants and oil refineries since the 1980s. In recent years it has also been used in power system balancing models.[1] Model predictive controllers rely on dynamic models of the process, most often linear empirical models obtained by system identification. The main advantage of MPC is the fact that it allows the current timeslot to be optimized, while keeping future timeslots in account. This is achieved by optimizing a finite time-horizon, but only implementing the current timeslot. MPC has the ability to anticipate future events and can take control actions accordingly. PID and LQR controllers do not have this predictive ability. MPC is a digital control.

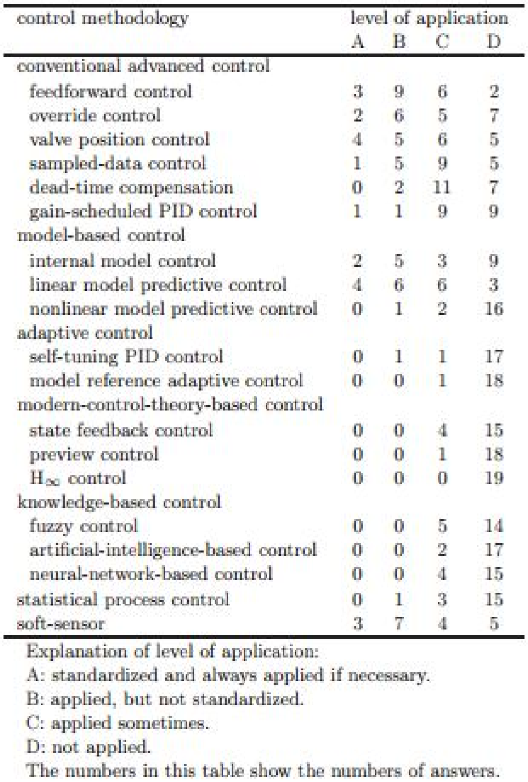


Structure of the predictive controller based on SVM Model



classification	methodology	application
modern advanced control	linear MPC	54
	nonlinear MPC	2
	LQI with preview action	2
conventional advanced control	feed-forward control override control valve position control analyzer feedback control model-based control etc	500+
regulatory control	PID/I-PD control	5006

Table1: Classification of Conventional and modern controls



control methodology	level of application			
	A	B	C	D
conventional advanced control				
feedforward control	3	9	6	2
override control	2	6	5	7
valve position control	4	5	6	5
sampled-data control	1	5	9	5
dead-time compensation	0	2	11	7
gain-scheduled PID control	1	1	9	9
model-based control				
internal model control	2	5	3	9
linear model predictive control	4	6	6	3
nonlinear model predictive control	0	1	2	16
adaptive control				
self-tuning PID control	0	1	1	17
model reference adaptive control	0	0	1	18
modern-control-theory-based control				
state feedback control	0	0	4	15
preview control	0	0	1	18
H_∞ control	0	0	0	19
knowledge-based control				
fuzzy control	0	0	5	14
artificial-intelligence-based control	0	0	2	17
neural-network-based control	0	0	4	15
statistical process control	0	1	3	15
soft-sensor	3	7	4	5

Explanation of level of application:
A: standardized and always applied if necessary.
B: applied, but not standardized.
C: applied sometimes.
D: not applied.
The numbers in this table show the numbers of answers.

Table2: Classification of control methodology and its level of application

IV. SIMULATION RESULTS

The conventional predictive control algorithms are mostly based on the linear system and SVM is used for fitting the nonlinear systems. So it is unfit for adopting SVM to GPC method. GPC method is an adaptive model predictive control method by online identification for model parameters and then used to implement multi-steps prediction and rolling optimization. So GPC has the both characteristics of general model predictive control and adaptive control. Due to adoption of traditional parameterized model with less parameters and easy to online identification, it is more flexible on system design by introducing unequal predictive level and control level. In practice, the optimization process repeats on the basis of feedback information, making GPC insensitive to modeling errors and environmental interference such uncertainties with the high adaptability, while the objective function taking into account the control increment sequence, making it suitable for large delays, non-minimum phase and *3118 2010 Chinese Control and Decision Conference* non-linear systems and so on. All of above provide conditions for good performances. Therefore, GPC has been a high degree of control engineering attention, and several new algorithms have emerged. successful applications in the industrial and aerospace. fields, although it has the shortcomings of large computation workload and difficult to restrain the overshoot.

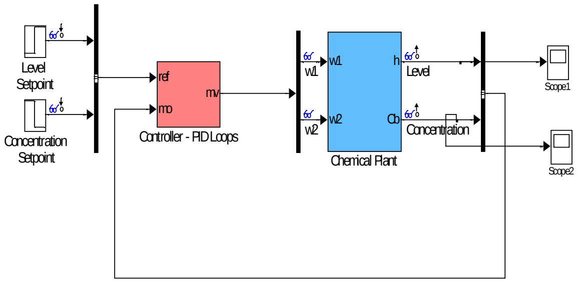
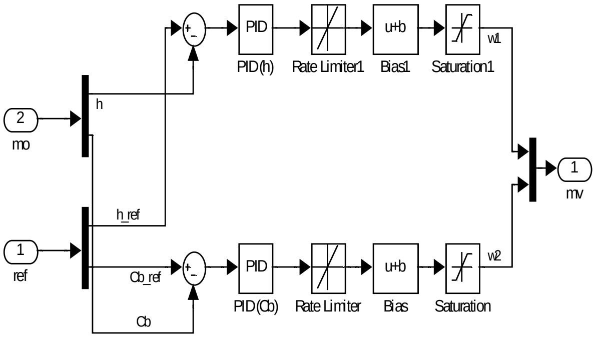


Fig 3 PID Controller



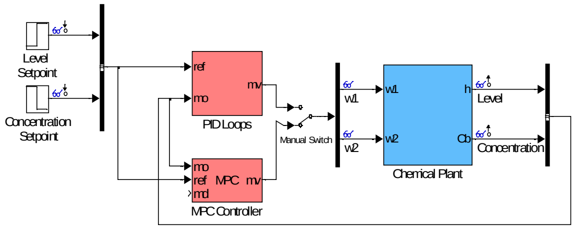


Fig 4 Model Predictive Controller

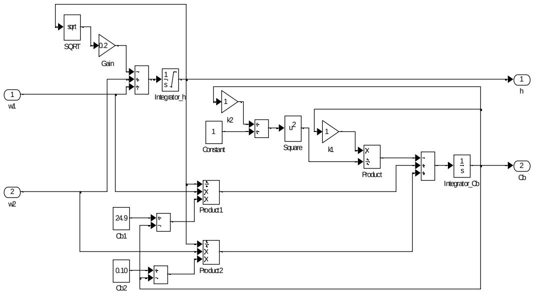


Fig 5 Subsystem of SMC controller

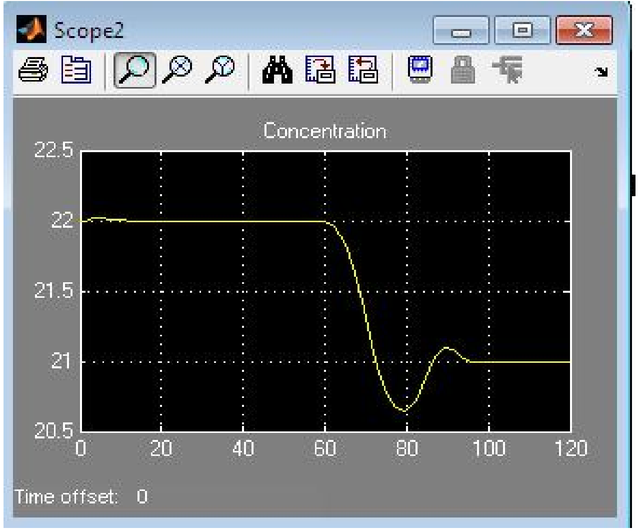


Fig 6 Concentration Versus time(Secs)

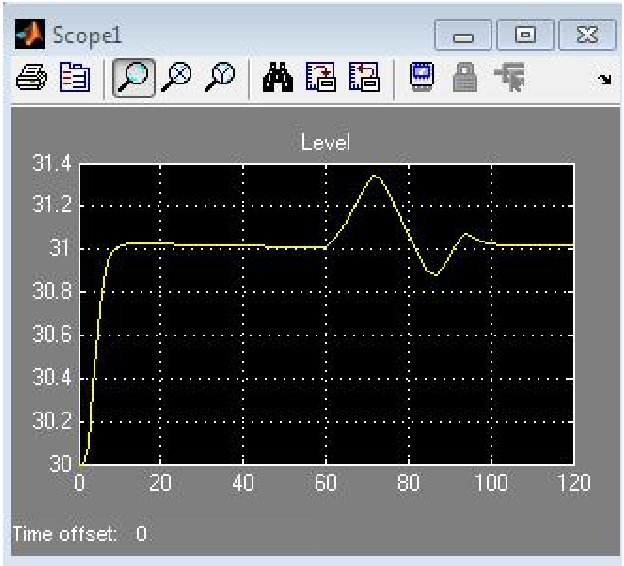


Fig 7 Level Versus time(Secs)

V. CONCLUSIONS

The paper presents the application of SVM modeling and predictive PID as controllers to control the temperature and pressure of the cement rotary kiln, and simulation results were derived. The results show that the presented method can reach satisfied performance by data training without pre-establishing accurate mathematical model and has strong robustness and better dynamic performance. It is expected that the presented method can give a reference for further development of advanced control schemes of rotary cement kiln and for industrial applications.

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