Study of Advanced Control Algorithm Based on Foundation Fieldbus

Yi-lin Zhou and shu-fen Qi
Department of Automation Electronic Engineering
Qingdao University of Science and Technology
Qingdao, China 266042

Wen-xia Zhang and Jian Yuan
Department of Automation Electronic Engineering
Qingdao University of Science and Technology
Qingdao, China 266042

Abstract - Based on the experiment platform of foundation fieldbus designed by Shen Yang Automation Institute of Chinese Academy of Science, the feasible project of applying advanced control algorithm to the single loop liquid control of foundation fieldbus control system is proposed, which exerts the technical advantages of foundation fieldbus and advanced control algorithm.

I. INTRODUCTION

The fieldbus control system (FCS) has more obvious advantage than the closed distributed control system (DCS), which has become the major in process control. Foundation fieldbus (FF) [1, 2] is an all-digital, serial, two-way communication system, is also developed specifically to meet the needs of process industries. It is therefore capable of handling all of the complexities of process management, including process variables, real-time deterministic process control, and diagnostics. In recent years, China has made great progress in developing FF products. For example, Shen Yang Automation Institute of Chinese Academy of Science offers a complete-line of FF products, including PC-based interfaces, fieldbus linking devices, distributed I/O, and configuration/diagnostics software, as well as Starter Kits. Designed as an industrial network specifically for distributed process control applications, FF represents the next generation in industrial communication standards for process control applications. In the industrial field, advanced process control (APC) [3] has been proved to deliver the huge benefits to the enterprises. With APC, FF is able to push the process control to a higher level of productivity, and is able to deliver bottom line improvement. Currently gaining popularity in the process industry is dynamic matrix control (DMC) algorithm, which can solve the control problems of complex production processes with great time varying and delay different from the conventional PID control algorithm.

Because Shen Yang Automation Institute of Chinese Academy of Science has only realized the conventional PID algorithm which can’t solve some complex control problems compared to DMC algorithm, the project of applying DMC algorithm to the single loop liquid control of FF system via the industry standard OLE for process control (OPC) protocol [4] is adopted in this paper. Equally, realize APC based on OPC server to prove the project.

II. FF-BASED EXPERIMENT PLATFORM

The control system includes two parts: FF and fieldbus control model (Fig.1). FF includes H1 and HSE (High Speed Ethernet). H1 (31.25 kbit/s) interconnects "field" equipment such as sensors, actuators and I/O; HSE (100 Mbit/s) provides integration of high speed controllers (such as PLC). Fieldbus control model can use traditional analog instruments in order to save investment. But those instruments needs fieldbus transmitters (NCS-IF105/NCS-FI105) to realize tradition simulation quantity and fieldbus numeral quantity interconversion.

Take the single liquid control loop for example, the softwares in computer run as follows:

1) Open HSE Init interface software, chooses the H1 link, the HSE interface software makes HSE I/O interface devices and H1 devices interconversion;
2) Open FF-Configurator configuration software, refresh links to get fieldbus devices list and fblock list, and then build application fblock configuration.(see fig.2);
3) Open FF H1 and FF HSE OPC server, refresh a time every second to realize the real-time data and historical data of devices sharing and alarm;
4) Open SiaView monitoring software, build a new project, put the PID module of objects in the view, and obtain a PID function block operation pane after connecting the OPC server.

Fig.1. The structure of the control system
However the controlled object in this paper adopts a two-tank process that is self-balanceable, vibrationless and interactive. The mathematics model can be described with the following transfer function:

\[ G(S) = \frac{K_P}{T_pS + 1} e^{-\tau S} \]

Where \( K_P \), \( T_p \), \( \tau \) are the gain, time constant and time-delay in process separately. Moreover, Shen Yang Automation Institute of Chinese Academy of Science has only realized the conventional PID algorithm that has an unsatisfied control effect.

To make that liquid control loop operate correctly, the parameters of function block should be revised. Double-click IF-PID function block, open the parameter window of the block, and change to the “auto” mode at the parameter of MODE_BLK.TARGET of IF_PID block. So applying DMC algorithm to FF system only needs to change the parameter of MODE_BLK.TARGET of IF_PID block to the “man” mode (see fig.3), and finally realize the process variables and control variables communication through OPC protocol.

\[ \text{OPC [5] is a collection of software programming standards and interfaces used in the process control industry. It is an open standard that permits a consistent method of accessing field data from plant floor devices. This method remains the same regardless of the type and source of data. OPC servers provide a method for many different software packages to access data from a process control device. Traditionally, any time a package needed access to data from a device, a custom interface, or driver, had to be written. The purpose of OPC is to define a common interface that is written once and then reused by any business or custom software packages. Once an OPC server is written for a particular device, it can be reused by any application that is able to act as an OPC client. OPC servers use Microsoft’s OLE technology (also known as the Component Object Model, or COM) to communicate with clients. COM technology permits a standard for real-time information exchange between software applications and process hardware to be defined. Therefore, use Visual Basic as an OPC client to communicate with any OPC server supporting the OPC Data Access 2.0.}

A. OPC SERVER

Select FF H1/HSE provided by Shen Yang Automation Institute of Chinese Academy of Science as OPC server. The OPC server offers only simple read/write semantics to access process variables. There is no support for Complex application specific data type. In addition, before an OPC client is able to access process variables of a particular process level device, corresponding OPC items have to be defined manually in the OPC server. Ideally, new devices would be able to generate “their” OPC items automatically upon connection to the fieldbus system. Fig.4 gives an overview of the OPC architecture as a whole.

B. OPC AUTOMATION INTERFACE

OPC client can use two sets of interfaces: custom interfaces and automation interfaces. Custom interface is the native C++ interface of COM; Automation interface is the interface offered in Visual Basic (VB), used in Word, Excel, ... Functionality is roughly the same in both models, automation interface is easier to use, but custom interface gives a more extended control.

C. OPC CLIENT

At first, OPC objects should be created in the OPC client, which is consistent with OPC server. The OPC access-data
A DMC PRINCIPLE

The original work developing DMC was developed by Cluter and others. DMC control [6, 7] is based on a discrete time step response model that calculates a desired value of the manipulated variable that remains unchanged during the next time step. When DMC algorithm is adopted, set the unit step manipulated value that remains unchanged during the next time step response model that calculates a desired value of the controlled variable as

\[
\Delta u(k) = (A^TQA + R)^{-1}A^TQ[w_p(k) - \tilde{y}_p(k)]
\]

Where, \(d^T = \begin{bmatrix} 1 & 0 & \cdots & 0 \end{bmatrix} (A^TQA + R)^{-1}A^TQ \)

B OPC CLIENT WITH DMC PRINCIPLE

DMC algorithm consists of three parts: predictive model, scrolled optimization and feedback emendation. The DMC algorithm in monitoring software has an effect on controlling the process.

When program DMC in OPC client with Visual Basic, abstract DMC control type to a class called DMC control (DMC Class), and correspondingly produce an object. The parameters of DMC control (such as the model time domain length \(N\), the optimized time domain \(P\), the control time domain \(M\) and so on) is considered as private of a DMC Class. The external program of DMC control objects cannot access to those data, but if take the DMC control initialization and the DMC control on-line computation as Public, the above data could be Written/read by the external program.

The controlled object of FF-based single liquid control loop is a two-tank liquid level container. The volume of each tank is 20cm\(\times\)10cm\(\times\)40cm. The controlled variable is the liquid height \(h_2\) of tank 2, its maximum value is 40cm and the set fluid value is 25cm. The DMC settings are the model time domain length \(N=10\), the optimized time domain \(6\), the control time domain \(5\) and the time interval \(1000\)ms. After choosing predictive time domain length and control time domain length, the control quality of dynamic step response value. At time \(k\), \(u\) has \(M\) continual increment changes, noted as \(\Delta u(k), \ldots, \Delta u(k + M - 1)\), and its predictive model is:

\[
\tilde{y}_M(k + i | k) = \tilde{y}_0(k + i | k) + \sum_{j=1}^{\min(M,i)} a_{i-j+1} \Delta u(k + j - 1),
\]

\(i = 1, 2, \ldots, N\)

The predictive output value \(\tilde{y}_M(k + i | k)\) affected by them in the future time \(P\) should be close to the value \(w(k + i), i = 1, 2, \ldots, P\) as far as possible, and the \(M\) control increments are softly restrained. The performance index can be written as:

\[
\min J(k) = \|w_p(k) - \tilde{y}_p(k)\|_Q^2 + \|\Delta u_M(k)\|_R^2
\]

Where,

\[
w_p(k) = \begin{bmatrix} w(k + 1) \\ \vdots \\ w(k + P) \end{bmatrix}, Q = \text{diag}(q_1, \cdots, q_P), R = \text{diag}(r_1, \cdots, r_M).
\]

All control increments can be calculated under the optimization of this performance index, through the predictive model above.

\[
\Delta u_M(k) = (A^TQA + R)^{-1}A^TQ[w_p(k) - \tilde{y}_p(k)]
\]

In order to read the collected data at any moment from OPC server, the collected data is put in the specified database (such as SQL Server 2000 database), which not only can fetch the data from the historical database in carrying on the algorithm simulation, but also refresh the real-time data along with the data collection to optimize the algorithm.

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systems mainly lies on erroneous power matrix Q and control power matrix R. Because the time-delay periodicity of controlled object, named as \( l \), is equal to 1, and it is impossible for the object to output tracked expected value corresponding to the time-delay, and the control power matrix R can be determined just after the actual debugging. Generally, a stable control of actual system can be carried out by increasing the value of R, but with the increasing of R, the dynamic response is extremely slow. R is chosen smaller in general. In this system the weighted coefficient of control is chosen as 0.1. Using the parameters chosen through the above principle, the real-time control curve can be shown just as Fig.6 and Fig.7.

Fig.6 Program DMC in OPC client with Visual Basic

Fig.7 The picture of DMC control with Visual Basic

VI. CONCLUSIONS

In this paper, DMC algorithm is an effective control technology for the single loop liquid control of FF system. Fundamental OPC technology is playing very important role in APC project execution.

Based on the FF fieldbus process control experiment system designed by Shen Yang Automation Institute of Chinese Academy and the OPC technology, first develop OPC client in Visual Basic through the OPC automation interface, and then realize the program to apply DMC algorithm in OPC client. At the same time, the specified database (such as SQL Server 2000 database) that is used to simulate the algorithms is studied. The more complex advanced control algorithm may use the OLE automation technology to realize the mixed programming of VB and Matlab, namely compile OPC client with VB to realize the data communication and carry on APC algorithm with Matlab, which is the key point in the future.

The weakness of today’s DMC is basically linear controller and limits its application areas. Non-linear model would be a new characteristic of the new generation of industrial technologies. Some new control technologies may also be incorporated in, such as model adaptation, data mining, and controller design under uncertainty.

ACKNOWLEDGMENT

The paper is supported by the national high-tech ‘863 project’. And during the researching and preparing the paper, many colleagues give their self-giving help. So, I will give my thanks for their great contribution.

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