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Application of ISP technology in the design of intelligent instruments

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Abstract. Intelligent signal processing (ISP) technology provides very important technical support for the design of intelligent instrument and meter in our country. In order to improve the application effect of ISP technology in the design of intelligent instrument and meter, the research status of ISP technology at home and abroad was firstly introduced, and then the construction and method of DMC and PID control algorithm model were expounded, finally, the data obtained from the model operation was analyzed and the conclusion was drawn. The results show that the DMC control algorithm has high application feasibility, and the application of ISP technology improves the stability of the output value of intelligent instrument. Based on the research results, the effect of algorithm model and technology application was summarized and the direction of improvement was clarified, so that some references were provided for the improvement of application effect of ISP technology.

Key words. ISP technology, intelligent instrument, instrument design.

1. Introduction

In recent years, the development of science and technology in our country is relatively fast. The rapid development of communication technology, network technology and semiconductor technology has brought important technical support for the development and design of intelligent instrument and meter system, and ISP technology has been one of the most important development techniques in system programming.

The emergence of ISP technology is the inevitable result of the development of system programming technology. The development of science and technology has greatly promoted the continuous prosperity of the intelligent equipment industry. Nowadays, all kinds of equipment, instruments and meters have been widely used in industrial production and daily life in the era of intelligent, and how to meet the needs of users for intelligent instruments and meters has become the main goal of the designers of intelligent instruments and meters. From the point of view of design,

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system programming technology plays a very important role in the whole design process of intelligent instrument and meter. ISP technology is widely used in all kinds of system programming technology, which is mainly related to its unique technical advantages and strong applicability. In addition, ISP technology has played a very important role in the development of digital systems. Therefore, how to further improve the effectiveness of ISP technology in the design of intelligent instrument and meter has become a very important topic to research.

Based on this, the application of ISP technology in the design of intelligent instrument and meter was analyzed and studied by constructing the model of control algorithm.

2. State of the art

Foreign scholars began to study ISP technology earlier, while the research on system programming technology starts late in our country, which is mainly because of the late development of computer network technology in China.

Miao proposed ISP technology originated in the semiconductor business, initially, the application of this technology focused mainly on the design and manufacturing of semiconductor products [1]. Wang believed that the emergence of ISP technology broke the shackles of traditional design technology, and played a revolutionary role in system programming [2]. Susa proposed that the application of ISP technology was simple and did not require more complicated basic equipment and process [3]. Ispled described the design features and intelligent applications of ISP technology, and he believed that this technology could be integrated with other systems in the design of instrumentation so as to achieve better design results [4]. Liu proposed that ISP technology was closely related to fuzzy logic control and artificial neural networks [5]. Ran described the application of ISP technology in intelligent sensor design, and proved the application of this technology in the design of intelligent instrument and meter to a certain extent [6].

The above studies are the introduction and discussion of the origin, development and application of ISP technology, although these studies have a detailed exposition of ISP technology, the research of this technology is too theoretical and lack of examples in the design of intelligent instruments and meters. Therefore, in view of the shortcomings of the existing research, the control algorithm model was proposed, and the application of ISP technology in the design of intelligent instrument and meter was analyzed and studied. In addition, the object of study and the specific content of the control algorithm model was described in the third part of this paper, and the specific data of the control algorithm model and simulation test was obtained and the data results were analyzed in in the fourth part; the last part was about the summary of the paper and the relevant conclusions.

3. Methodology

The application of ISP technology in the design of intelligent instrument and meter was studied mainly by constructing the integrated control algorithm model of intelligent instrument. Most intelligent instruments are integrated control algorithms, such as Schneider Electric's inverter and PLC are integrated with PID control algorithm, so that the usability of the instrument is stronger, and the composition of the control loop is simpler. The design of the intelligent instrument in this paper also integrated two control algorithms: PID algorithm and DMC algorithm.

Limited believed that PID controllers (also known as PID regulators) controlled by the ratio (P), integral (I) and differential (D) in process control are the most widely used automatic controllers [7]. They have the advantages of simple principle, simple realization, wide application scope, independent control parameters and simple selection of parameters. Moreover, it can be proved that PID controller is an optimal control for the typical object of process control - "the first order lag + pure lag" and "the second order lag + pure lag" control object. There are three simple PID control algorithms in the control point, which are incremental algorithm, position algorithm, and differential first. Chinmoy believes that although these three PID algorithms are simple, they have their own characteristics and can basically meet most of the requirements of general control [8].

Table 1 shows the basic control parameters of the PID algorithm. Mohanrao held that algorithm of PID controller design is the most commonly used controller, and the control system is composed of PID controller and controlled object [9]. PID controller is a kind of linear controller, there is difference between the input setting value and the output feedback value constitutes the feedback bias, the better control effect can be obtained by correcting the deviation, and the control law can be deduced according to this basic principle.

Table 1. PID control parameters

Mode	Channel	Set point	Parameter KP	Parameter TI	Parameter TD
0/1/2	0–7	0–100	0–100	0–100	0–100

The construction process of the PID control algorithm model is as follows:

Firstly, the following formula is applied to calculate the control increment parameter.

$$\Delta MV(t) = K_{\mathrm{p}} \left[DV(t) + \frac{1}{T_i} \int DV(t)\,\mathrm{d}t + T_{\mathrm{D}} \frac{\mathrm{d}(DV(t))}{\mathrm{d}t} \right] . \tag{1}$$

Here, t is the sensing time of intelligent instrument, M is the control quantity of algorithm model, V is the data delay, D is a variable coefficient, and $\Delta MV(t)$ is the control increment.

Secondly, the following formula is applied to calculate the control quantity of the control algorithm model, and the time constant and the deviation coefficient are the main parameters for calculating control quantity and control rate.

$$MV(t) = MV(t) + \Delta MV(t)\,. \tag{2}$$

Thirdly, generally speaking, the controller of intelligent instrument and meter is usually designed by the programming language C. According to this practical situation, the control algorithm parameters obtained by the above operations was needed to be discretized, so as to obtain the specific sampling data points and computing time. The discretization operation is shown in the equation

$$\Delta MV(k) = K_{\rm p}\left[e(k) + \frac{T}{T_i}\sum_{i}^{k} e(i) + \frac{T_{\rm d}}{T}(e(k) - e\,(k-1))\right]. \tag{3}$$

Here, k is the sampling time point, T is the computing time, p is the initial sampling time, and e is the output parameter of the instrument controller.

Fourthly, after the discretization operation, the obtained sampling period and time point are needed to use the following formula to further process the algorithm model, so as to obtain the algorithm base model with higher accuracy.

$$\Delta MV = \Delta MV(k-1) + q_0 e(k) + q_1 e(k-1) + q_2 e(k-2)\,, \tag{4}$$

where q is the value of sample period.

Fifthly, the following formula is used to determine the final algorithm model. In general, the algorithm model obtained by operation has a better control effect and more stable control rate. At the same time, tracking speed and accuracy are also important indexes to measure the effectiveness of the algorithm model.

$$\Delta MV = K_{\rm p}\left\{[e(k) - e(k-1)] + \frac{T}{T_i}e(k) + \frac{T_{\rm d}}{T}\left[e(k) - 2e(k-1) + e(k-2)\right]\right\}, \tag{5}$$

where $T_{\rm d}$ is the sampling time for the peak amount of control.

DMC, dynamic matrix control, is a computer based control technique, which is an incremental algorithm and the unit-step response based on the system, and it is applicable to stable linear systems. The dynamic characteristics of the system have pure hysteresis and do not affect the direct application of the algorithm. Deng believed that the standard DMC control algorithm is a very successful application in control systems based on DMC, however, there is a big problem when it is applied directly to the network environment [10]. In the case of low network load, the network delay is very small, the impact on the control system is almost negligible, and so the DMC algorithm has fast response, smooth transition and good control effect. Table 2 shows the basic parameter of the DMC control algorithm. Paul believed that the control structure of DMC is mainly composed of prediction model, rolling optimization, error correction and closed-loop control [11]. The predictive control algorithm is divided into model predictive control, generalized predictive control, and predictive control with internal model structure. The core idea of any algorithm includes three parts: prediction model, receding horizon optimization and feedback correction.

Table 2. DMC algorithm parameters

Manual value	Size of DMC forecast step	The period of sampling	Size of DMC control step	DMC control parameters
0–4	0–100	100–10000	0–100	0.001–0.1

Liu believed that predictive control is a model-based control algorithm, this model is called predictive model [12]. The function of the prediction model is to predict its future output according to the object's historical information and future inputs. As a result, the future control strategy arbitrarily can be given as in the case of system simulation, the output changes of the observation object under different control strategies can be used to compare the quality of these control strategies, and the optimal control strategy is determined and controlled. The prediction model is constructed as follows: firstly, the sampling and sorting of the raw data are performed according to the unit step response of the controlled object, and the sampling period is also determined. In general, sampled data is the raw data for model nonparametric tests. Secondly, the linear processing of data analysis is carried out, and the concrete operation of model control increment is completed according to the following formula (6), finally, data output of the prediction model and value of model output is obtained.

$$\tilde{y}_1\left(k+\frac{i}{/}k\right)=\tilde{y}_0\left(k+\frac{i}{/}k\right)+a_i\Delta u(k)\,. \tag{6}$$

Here, k and i are the regression coefficients and increment coefficients of the control variables, $\tilde{y}_0\left(k+\frac{i}{/}k\right)$ is the model output value, and $a_i\Delta u(k)$ is the sampling sequence.

Predictive control is an optimization control algorithm, which is to determine the optimal future control role through a certain performance indicators, this performance indicator relates to the future behavior of the system. Aboozar believed that the optimization of predictive control is very different from the discrete optimal control in the traditional sense, which is mainly manifested in the optimization of predictive control that is a priority interval for receding horizon optimization [13]. At each sampling point, the optimization interval moves forward at the same time. Therefore, predictive control isn't based on a global optimization performance index, but at each point there is an optimal performance index relative to that time. The relative form of the performance indicators at different times is the same, but the absolute form and the time zone included are different. Therefore, optimization isn't carried out off-line at once, but is carried out online repeatedly in predictive control, that is called rolling optimization. The optimization process is on-line optimization over time repeatedly. Wang believed that every step is to achieve a static optimization, but it is dynamic optimization from the overall perspective [14]. This is the meaning of rolling optimization, and also the fundamental point of predictive control that is different from the traditional optimal control. The process of rolling optimization is that the starting point of a certain time is determined as the starting point and the control increment is calculated, and then the forecast value is calculated according to the following formula, and finally the optimal index is determined by comparing the predicted value.

$$\Delta u(k) = (B_T QB + r)^{-1} B^T Q \left[w_p(k) - \tilde{Y}_{p0}(k) \right] . \tag{7}$$

Here, B and Q control the optimization factor and the dynamic coefficient of the variable, w is the setting value of the control increment, $\tilde{Y}_{p0}$ is the input value of the sampling time, and $\Delta u(k)$ is the predictive value of the rolling optimization.

Zhang believed that predictive control is a closed-loop optimization control algorithm, after a series of future control roles are identified by optimization, it is usually not the full implementation of these control functions, but only the control of this moment to prevent the deviation of the model from the ideal state due to model mismatch or environmental interference [15]. At the next sampling time, the actual output of the object is detected first, the model based prediction is corrected by using this real-time information, and then the new optimization is carried out. The form of feedback correction is various, no matter what kind of correction form, the optimization of predictive control is based on the actual system and tries to predict the dynamic behavior of the system accurately in the optimization. Therefore, the optimization in predictive control not only is based on the model, but also uses the feedback information, thus closed-loop optimization is constituted. In the application of the DMC algorithm model, the feedback correction usually is used the following formula to correct the error through the detection of actual output and the predicted value.

$$\tilde{Y}_{\rm cor}(k+1) = \tilde{Y}(k) + He(k+1) , \tag{8}$$

where $\tilde{Y}_{\rm cor}(k+1)$ is the feedback error of $k+1$ sampling time points, $\tilde{Y}(k)$ is the sampling output prediction value, and H is the feedback correction coefficient.

The method of constructing PID and DMC control algorithm was used and the experiment was simulated to study the application effect of ISP technology in intelligent instrument design. ISP technology is widely used in the design of intelligent instrument and meter, and its application is more complicated. The method of model control algorithm research can be simulated in a certain extent so as to ensure the accuracy of the application of the algorithm model and provide a more favorable reference basis and basis for the study.

4. Result analysis and discussion

The results of the algorithm model analysis obtained by the methods described above are shown in several tables.

Table 3 shows the data results of the intelligent instrument test by using ISP technology, which is obtained through PID control algorithm model and DMC control algorithm model respectively. The data show that the accuracy of the data obtained by the DMC control algorithm model is higher. So it can be seen that the

DMC control algorithm model has a high feasibility in the research of ISP technology application.

Table 3. Comparative analysis of model output values

Frequency	PID output value	DMC output value
50	100.10	4.9997
50	100.50	2.4995
50	101.10	1.0001
50	100.02	0.5000

The rolling optimization method described in the third part above was used to carry on the model computation and the simulation test after the DMC model was carried on the scroll optimization. The results of the data obtained comparison are shown in Fig. 1. The data showed that the change trend of the test results of the three experimental models was more obvious after rolling optimization, and the trends of the three experimental models had a higher similarity. It was obvious that the data obtained by the algorithm after rolling optimization was more convincing, and the overall output level of the intelligent instrument was obviously lower than that of the original model. The stability of the simulated test output of the intelligent instrument was still poor. Therefore, the feedback correction was applied below to further improve the algorithm model and test results.

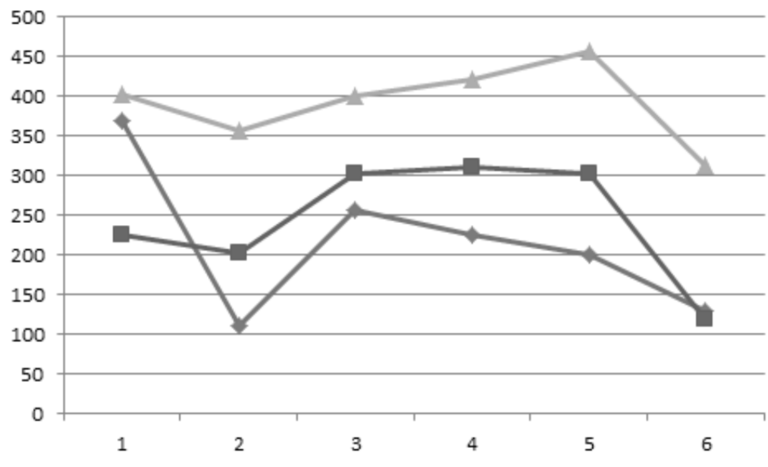

Fig. 1. Rolling optimization data of algorithm model

As shown above, the simulated results obtained after feedback correction of the control algorithm model are shown in Fig. 2. The data showed that the data stability of the DMC algorithm model and the simulation test was better, and the data change trend of the three test algorithm models was stable. Therefore, the optimized DMC model was used to test the influence of ISP technology on the design of intelligent instrument and meter.

In order to better verify the application of ISP technology in the design of intelli-

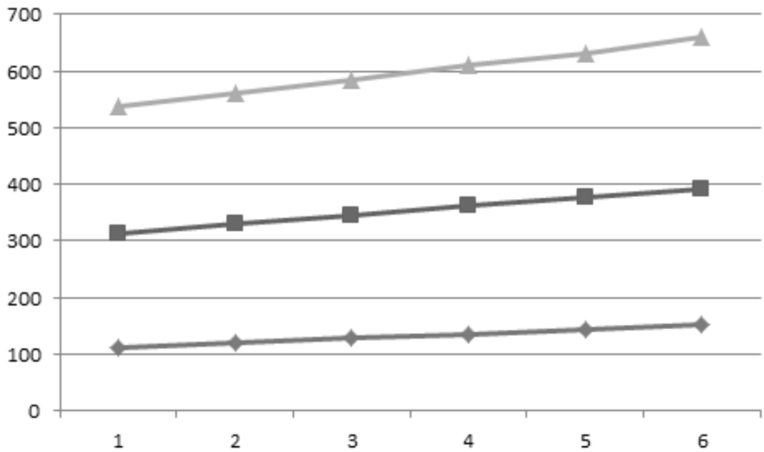

Fig. 2. Comparative analysis of the feedback data of the algorithm model

gent instrument and meter, in this paper, the intelligent arithmetic model was used to test the three basic indexes of voltage, current and power, which weren't designed by using ISP technology. The test results are shown in Table 4. The data showed that the average voltages, current and power index of common intelligent instruments changed greatly, however, the range of change was relatively small and the test results of raw data were less stable, therefore, the stability of ordinary intelligent instruments needed to be improved.

Table 4. Experimental results of application of ISP technology

U (V)		I (A)		P (VA)	
Standard value	Measured value	Standard value	Measured value	Standard value	Measured value
100	100.80	5	4.8997	500	500.12
100	100.50	5	5.0002	500	489.96
100	101.10	5	4.8999	500	498.89
100	100.02	5	4.8959	500	500.02
100	100.06	5	5.1010	500	510.10
100	101.02	5	5.2021	500	479.20

Table 5 shows the specific data of the voltage, current and power obtained by the instrument after the improved design of the general intelligent instrument described above by using ISP technology. The test value and the standard value of the three parameters of the intelligent instrument were improved by the ISP technology, and the range of change was small and could be negligible, so it could be seen that the stability of the test output of the intelligent instrument designed by ISP technology was high.

Table 5. Experimental results of ISP technology application

U (V)		I (A)		P (VA)	
Standard value	Measured value	Standard value	Measured value	Standard value	Measured value
100	100.10	5	4.9997	500	500.09
100	100.20	5	5.0002	500	499.96
100	100.10	5	4.9999	500	499.89
100	100.02	5	4.9959	500	500.02
100	100.06	5	5.0010	500	500.10
100	100.08	5	5.0021	500	499.20

To sum up, the intelligent instrument designed by this technology has a better stability and higher practicability, so the application of ISP technology for the design of intelligent instruments can improve the overall performance of the instrument. However, because the application of ISP technology in intelligent instrument and meter is related to the adjustment of artificial neural network threshold, although this problem has some influence on the application of ISP technology in the design of intelligent instrument and meter, the degree of influence is small and can be ignored. Therefore, the author believes that the application of ISP technology in intelligent instrument design is better, but its scope of application still needs to be further expanded. First of all, ISP technology will be applied to the sensor circuit design and extended to other intelligent instrumentation device design from the perspective of sensor design. Secondly, the simulation research of ISP technology in the design of intelligent instrument and meter should be strengthened from the point of view of artificial neural network, so as to improve the actual application effect of technology. Finally, the control parameters should adjusted in the design process, so that the technical advantages can be actively applied to the instrument design, the functionality of the intelligent instrument and meter can be promoted, and the intelligent production of the device can be promoted.

5. Conclusion

In order to improve the application effect of ISP technology in the design of intelligent instrument and meter, the influence of ISP technology on the design of intelligent instrument and meter was analyzed and studied by building a multi-control algorithm model. Finally, the main conclusions were as follows: the data results obtained by performing simulation tests of the DMC control algorithm model have high accuracy. The application of ISP technology can improve the accuracy and stability of the output of intelligent instruments and meters to a certain extent, but the technique still has the problem of adjusting the threshold of the artificial neural network.

To sum up, the model of the control algorithm used in this paper has a high rationality and comprehensiveness, the application of the algorithm model is beneficial to the application of ISP technology to improve the design direction of intelligent instruments. However, there are still problems that are not conducive to the adjustment of the threshold of the artificial neural network. Therefore, although this study has a certain reference value, there are still some shortcomings. In the future research, the application scope of system programming technology should be expanded and the application effect of ISP technology in intelligent instrument design should be enhanced by reasonably adjusting the control parameters of instruments and meters.

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