The optimization method of control precision of injection system in well metering

Haochen Zou

The seventh operation area, the No.6 oil production plant, Daqing Oilfield Co., Ltd., Daqing, China

Abstract: Based on the analysis of the current situation of single well metering, data acquisition and control mode of oilfield injection system, the data acquisition and control mode of polymer injection volume and dilution water injection volume of single well were optimized and improved respectively. The automatic control of injection volume of single well was realized, the injection accuracy and time effect of metering and control were enhanced, and the work intensity of employees was reduced. Meanwhile, the polymer and dilution water injection volume and the abnormal alarm function of water metering regulation were increased. These make the operation of flow regulator, pump and other equipment in injection station more reasonable, and improve the operation life and efficiency of system equipment.

Keywords: Injection accuracy; data acquisition; well metering.

1. Field automatic control injection accuracy

The situation of 34 injection stations in Oilfield at the injection site was investigated. 10 wells were selected for each station, and 340 single wells were selected for automatic control. Before optimization and improvement, the injection volume of single wells was completely controlled by automatic control. Compared with the injection allocation value of the scheme, the average compliance rate of the injection scheme of the injection station after 24 hours of continuous production was 81.79%, the coincidence rate with the injection scheme of polymer flooding injection station required by the management is ± 5%, with a difference of 13.21%.Therefore, it is still necessary to manually regulate the injection volume of a single well. The survey data of some polymer injection wells are shown in Table 1.

Table 1 questionnaire of automatic control production before optimization and improvement of some injection stations

Well number	injection	Instantaneous injection (m3/h)	9:00	11:00	14:00	Difference between two table bases (m3)	5-hour automatic control error rate%
	medium		Table base (m3)	Table base (m3)	Table base (m3)		
1# injection well	water	1	12551.8	12553.8	12556.8	5	0
	mother liquor	0.46	824.8	825.7	827	2.2	-4.35
2# injection well	water	0.96	9356.6	9358.6	9361.4	4.8	0
	mother liquor	0.29	625.6	626.1	627	1.4	-3.45
3# injection well	water	0.83	6462.1	6463.8	6466.3	4.2	1.2
	mother liquor	0.21	491.1	491.5	492.1	1	-4.76
4# injection well	water	0.79	6157.7	6159.2	6161.5	3.8	-3.8
	mother liquor	0.25	711.9	712.4	713.2	1.3	4

2. Optimization and improvement of injection metering control technology

2.1 Workflow and algorithm of automatic control of polymer injection volume

Firstly, manually input the injection volume of single well scheme into the main control computer, and PLC automatically collects the actual injection volume fed back by polymer flow meter through 485 communication,

* Corresponding author: zouhaochen@petrochina.com.cn

calculates the actual injection volume of polymer in the configuration software, and runs the program regularly.(the actual injection volume in this period is obtained by subtracting the accumulated volume base of the polymer instrument being recorded from the accumulated volume base of the polymer instrument recorded last time) the main control computer regularly compares the actual injection volume with the set injection volume. When there is a deviation between the actual injection volume and the set injection volume, the control program of the main control computer calculates the injection volume value to be corrected through the formula. This calculation process works circularly on the main control computer, constantly refreshing and generating new set injection volume.

Calculation formula for automatic control of polymer injection volume:

$$S_n = S_{n-1} - (\frac{V_n - V_{n-1}}{T}) + F \quad (1)$$

S_n - the nth set injection volume (m^3/h);
S_{n-1} – the n-1th set injection volume (m^3/h);
V_n - base number of the nth polymer flow meter (m^3);
V_{n-1} - base number of n-1th polymer flow meter (m^3);
F - injection volume of scheme (m^3/h);
T - calculation cycle interval (H).

2.2 Method for judging rationality of setting value of polymer injection volume

For the rationality of the set value of polymer injection volume, the following design is carried out.

Determination of the upper limit value of polymer injection volume: when the new set volume is greater than the maximum displacement (P_{max}) of the pump, the equipment cannot adjust and compensate the difference of the previous period back to the injection volume of the scheme in the next period, indicating that the equipment is not operating normally, so it is necessary to alarm and remind the on-site operators for maintenance and inspection. That is, when $S_n > P_{max}$, the alarm will be prompted.

Determination of the lower limit of polymer injection volume setting: due to the maximum working displacement (P_{max}) of the injection pump, when the set displacement is less than 40% of the actual maximum displacement, the pump operation frequency will be less than 20Hz, resulting in the motor being lower than the reasonable operation frequency. It is necessary to alarm and remind the on-site operators for maintenance and inspection. That is, when $S_n < 40\% P_{max}$, the alarm will be prompted.

Upper limit alarm formula of polymer injection volume setting:

$$P_{max} - [(S_{n-1} - \frac{V_n - V_{n-1}}{T}) + F] < 0 \quad (2)$$

Polymer injection lower limit alarm calculation formula:

$$(S_{n-1} - \frac{V_n - V_{n-1}}{T}) + F < 40\% P_{max} \quad (3)$$

P_{max} - actual maximum displacement of pump (m^3/h).

2.3 Optimization of PLC polymer instantaneous flow data acquisition mode

At present, the PLC data acquisition polling method is used for periodic acquisition, and the data processing method is to directly apply the collected data and participate in the control. In this way, it is easy to collect the instantaneous peak, trough value and system noise of the on-site flowmeter. If the collected abnormal data is directly involved in the internal control of PLC, it will cause the instantaneous fluctuation of the frequency converter and affect the stable injection and the service life of the equipment. In view of this problem, the PLC data acquisition mode is optimized, and the mode of directly participating in the control of the original data is changed to participating in the calculation after data statistics.

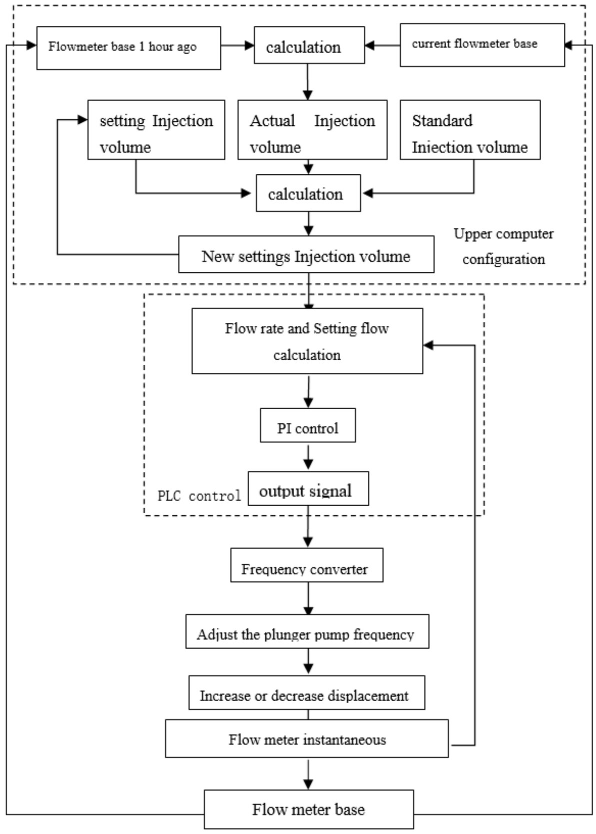

Fig. 1 work flow chart after optimization and improvement of polymer regulation and metering control system

3. Study on the reasonable range of allowable error of flow controller

According to the on-site staff who do not perform automatic adjustment when they reflect the slight difference of the field flow controller, carry out field test, and determine that the cause of the problem is the "dead zone" setting range of PID control module (the dead zone is the common name of the maximum allowable error). The normal "dead zone" control is to reduce the number of actuator actions, (generally, a "dead zone" is set for PID regulator. In ± "dead zone", the input deviation is considered to be 0. When the dead zone is exceeded, the

 https://doi.org/10.1051/e3sconf/202337501035

input deviation will be calculated from 0. The dead zone can effectively reduce the number of actuator actions and ensure the equipment used.) However, because the dead zone is set too large, the adjustment accuracy is reduced, so the "dead zone" range of flow controller is tested on site, and the reasonable "dead zone" range is determined to be 0.05 m^3 / h.

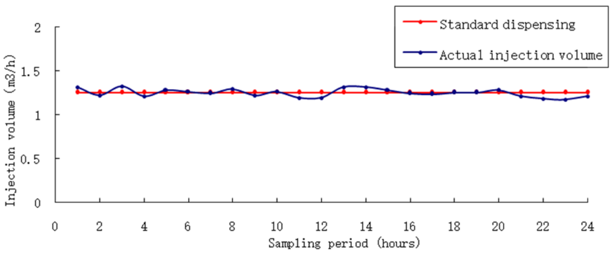

Figure 2 regulation of setting dead zone range 0.05 m^3/h

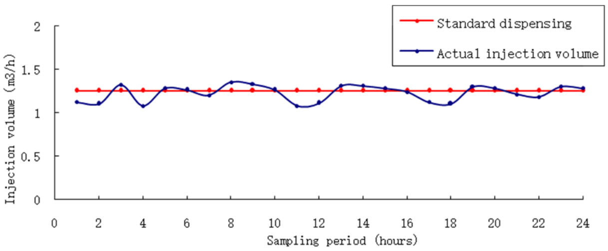

Figure 3 regulation of setting dead zone range 0.1 m^3/h

According to the research results of the optimization of the dilution water injection metering control system, the flow chart of the dilution water metering control system is given, and the program is written and implemented on site.

4. Application effect

The improved metering control system will be optimized and field test will be carried out in three injection stations in the oilfield. Similarly, the injection plan of three injection stations will be injected for 24 hours continuously. The average compliance rate of injection schemes of three injection stations is 98.36%. The injection scheme of polymer flooding injection station which fully meets the management requirements is within ± 5%, and it can achieve automatic control without manual intervention.

Table 2 questionnaire of automatic control production after optimizing and improving injection wells in three injection stations

Well number	Injection	Instantaneous injection (m3/h)	9:00 Table base (m3)	11:00 Table base (m3)	14:00 Table base (m3)	Difference between two table bases (m3)	5-hour automatic control error rate %
1# injection well	water	0.83	8737	8738.64	8741.17	4.17	0.48
	mother liquor	0.21	1055	1055.45	1056.07	1.07	1.90
2# injection well	water	1.17	15759	15761.34	15764.86	5.86	0.17
	mother liquor	0.5	2216	2217.00	2218.50	2.50	0.00
3# injection well	water	1.29	16916	16918.60	16922.50	6.50	0.65
	mother liquor	0.58	2614	2615.19	2616.93	2.93	0.46
4# injection well	water	1.75	17146	17149.52	17154.79	8.79	0.46
	mother liquor	0.54	1428	1429.10	1430.68	2.68	-1.05

5. Conclusion

(1) Recognizing the existing problems of metering control at this stage, new improvement schemes are proposed for the injection volume control of polymer and dilution water respectively, and the precise regulation of injection volume of polymer injection well based on base matching is proposed to effectively improve the metering control capacity of injection station.
(2) Aiming at the problems existing in the metering control, the optimization and improvement are carried out, and the interconnection among the flow controller, dilution water metering flowmeter, frequency converter, mother liquor metering flowmeter, PLC and main control computer is realized, which provides a feasible path for the signal transmission and linkage control between the control units in the automatic control system of the injection station.
(3) By setting the maximum control range of the hourly injection volume of each single well, judge the injection volume automatically written in every hour, give an alarm when the hourly injection volume is too large, and remind the staff on duty to deal with it, so as to realize the

https://doi.org/10.1051/e3sconf/202337501035

optimization of the alarm prompt of insufficient metering control of single well pump efficiency in the injection station.

(4) Through the optimization and improvement of the injection automatic control system of polymer injection station, the accuracy of unmanned automatic injection has been improved from 81.79% of the original scheme to 98.36% of the current scheme, and the quality of polymer injection has been well guaranteed.

References

1. Wang Gang Research on remote centralized control management in industrial automation system [J]China informatization, 2013,5:42-48
2. Zhao Yuanjun Development and application of general server OPC [D]Shanghai: Shanghai Jiaotong University, 2004
3. Ding Yuhui Lou Wenfa Li Junhong Integrated automation system of coal mine based on iFix. China's high-tech enterprises, 2014,3:20-26.
4. Li Yun; Wang Wei Application of flow meter in automatic control system [J]Chemical design communication. 2016042,91
5. in TianjinDesign and Research on automatic control system of polymer injection device [D]China University of petroleum. October 2008