Design of the Sequential Control System for Programmable Logic Controller based on Computer Aided Technology

Cunzhi Yao[1*] and Yingjie Wang[2]

[1]School of Artificial Intelligence, Zhengzhou Railway Vocational and Technical College, Zhengzhou, Henan 451460, China, yaocunzhi212@163.com
[2]School of Artificial Intelligence, Zhengzhou Railway Vocational and Technical College, Zhengzhou, Henan 451460, China, wyjlw18@163.com

Corresponding author: Cunzhi Yao, yaocunzhi212@163.com

Abstract. The controller commonly used in industrial system is mainly PLC programmable logic system controller, which is essentially a digital operation electronic system, and it is completely suitable for industrial environment. However, with the continuous expansion of the industrial industry, the corresponding scale continues to expand, the industrial control system is not only limited to PLC control alone, it needs to work in coordination with the computer, the conventional computer-aided PLC control system design still has poor compatibility, high complexity and relatively high development cost. In this paper, with the air pressure control system of pneumatic transmission equipment as the carrier, based on the object-oriented computer-aided PLC control system for system level development, and based on this design, the overall architecture of the computer-aided PLC control system is designed, and the operation mechanism of the architecture is described in detail. In the experimental part, the traditional pneumatic control circuit is reformed and designed based on the PLC control system under the computer assistance, and the sequence control program suitable for its use is proposed. The experimental results show that the design scheme and the corresponding sequence control algorithm proposed in this paper are relatively reasonable, and the corresponding program runs safely and reliably, and the corresponding scalability also has certain advantages.

Keywords: Computer aided design; PLC control system; sequence control system; air pressure control loop system; system architecture design
DOI: https://doi.org/10.14733/cadaps.2022.S4.79-89

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

1 INTRODUCTION

With the continuous development of industrial scale and industrial automation, its corresponding production efficiency, industrial production accuracy and corresponding product stability are more and more restricted by the industrial control system [1]. At present, the corresponding controllers in the industrial control system are mainly PLC programmable controllers. The PLC control system has experienced the transformation from single-chip centralized control to systematic integrated control. The corresponding PLC control system is more standardized, intelligent and networked. At the same time, it also faces more complex system control [2]. The continuous development of computer technology makes the computer-aided PLC control system more and more mature. The traditional computer-aided PLC control system is mainly composed of PC program end and corresponding PLC program end in the control system structure, which has the disadvantages of poor compatibility, high development cost and difficulty in actual development and operation [3]. Therefore, the research and development of a stable and expandable computer-aided PLC control system has become an important topic in the industrial control system [4-5].

In the field of PLC industrial control system and the research level of computer-aided PLC control system, a large number of researchers and related industrial companies have done a lot of work and scheme design. In the corresponding PLC industrial control application field, the well-known PLC control systems in the industrial field mainly include the virtual machine PLC control system proposed by Fujisawa et al. [6], the embedded PLC control system based on Windows proposed by Eguti and Trabasso [7], the real-time PLC industrial control system based on RTLinux proposed by Otte et al. [8], and Bibikov et al. [9] proposed the corresponding PLC industrial control software, in which the corresponding SoftPLC industrial control software system is a typical traditional industrial control system, which is essentially an open source control software. Based on the open industrial control system, industrial enterprises can combine their own needs with computer technology, which supports different analog signals and digital signals The corresponding I / O interface supports the programming of multiple high-level languages, but the industrial control software lacks the cooperation of computer technology, and its corresponding flexibility is poor; in the research of corresponding computer-aided PLC industrial control system, Khan and other researchers put forward that computer-aided PLC control, as an extension of PLC control system, essentially adds computer technology to PLC control system as the control component of PLC control system [10]. At the same time, it has great advantages in object-oriented design. At present, there are still serious problems in the corresponding integration of traditional computer-aided PLC control system the current mainstream computer-aided PLC control system is mainly customized for a certain industrial control scene, which often has a strong purpose. In essence, it uses a special function of the computer to repackage a certain control function in the PLC control system. It does not consider the application of computer-aided technology in PLC industrial control system from the overall architecture Therefore, based on this computer-aided PLC control system, the corresponding development difficulty is increased, and the corresponding system compatibility is also relatively poor; in the corresponding computer-aided PLC control system, the corresponding interface definition and development standards are still in serious shortage.

Based on the above problems of the computer-aided PLC control system, this paper will use the air pressure control system of pneumatic transmission equipment as the carrier, develop the system level based on the object-oriented computer-aided PLC control system, design the overall architecture of the computer-aided PLC control system, and elaborate the operation mechanism of the architecture. In the experimental part, the traditional pneumatic control circuit is reformed and designed based on the PLC control system under the computer assistance, and the sequence control program suitable for its use is proposed. The experimental results show that the design scheme and the corresponding sequence control algorithm proposed in this paper are relatively reasonable, and the corresponding program runs safely and reliably, and the corresponding scalability also has certain advantages.

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

The corresponding structure of this paper is as follows: in the second section of this paper, based on the corresponding hardware architecture and software architecture of PLC and computer, the communication architecture and protocol of PLC control system under computer assistance are designed and analyzed, and the corresponding PLC control system architecture under computer assistance is given; in the third section of this paper, the communication architecture of PLC control system under computer assistance is analyzed At the same time, the corresponding experimental results are analyzed and studied. Finally, this paper will summarize and prospect the follow-up research.

2 THE ANALYSIS OF PLC SEQUENCE CONTROL SYSTEM WITH THE AID OF COMPUTER

This section will focus on the analysis of the corresponding communication architecture and protocol of the computer-aided PLC control system, and give the architecture of the whole computer-aided PLC control system. As shown in Figure 1.

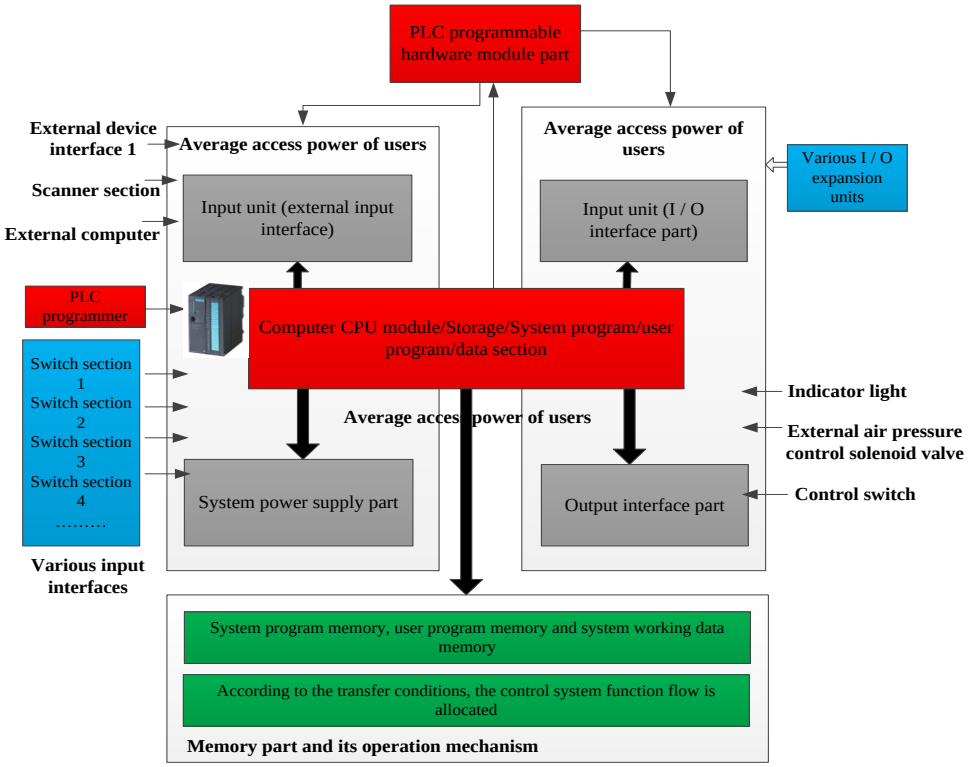

Figure 1: The application frame of PLC control system in industrial scene.

The operation diagram of PLC control system in the corresponding industrial control scene under computer assistance is shown. From the figure, it can be seen that the computer and the corresponding PLC hardware are controlled and regulated by the central processing unit MCU. At the same time, there are memory, I / O unit and corresponding programmer in the corresponding control system, and the corresponding memory includes the whole system program memory and user program Sequence memory and system working data memory. It can also be seen from the figure that in the corresponding sequence control link, the control system mainly uses the sequence function language to meet the sequence logic control of the whole system. When writing

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

the corresponding program, the corresponding sequence process needs to be divided and transformed step by step, and the corresponding control system function process needs to be allocated according to the transfer conditions, so that the industrial process can follow the set industrial process Each control step corresponds to a control function module. At the same time, all the processes are carried out under the corresponding coordination of the computer.

2.1 Protocol Analysis of PLC Sequence Control Communication Architecture under Computer Assistance

Considering the generality and compatibility of PLC and computer communication protocol, this paper mainly uses host link communication protocol as the communication protocol of PLC control system under computer assistance. The corresponding protocol framework is shown in Figure 2.

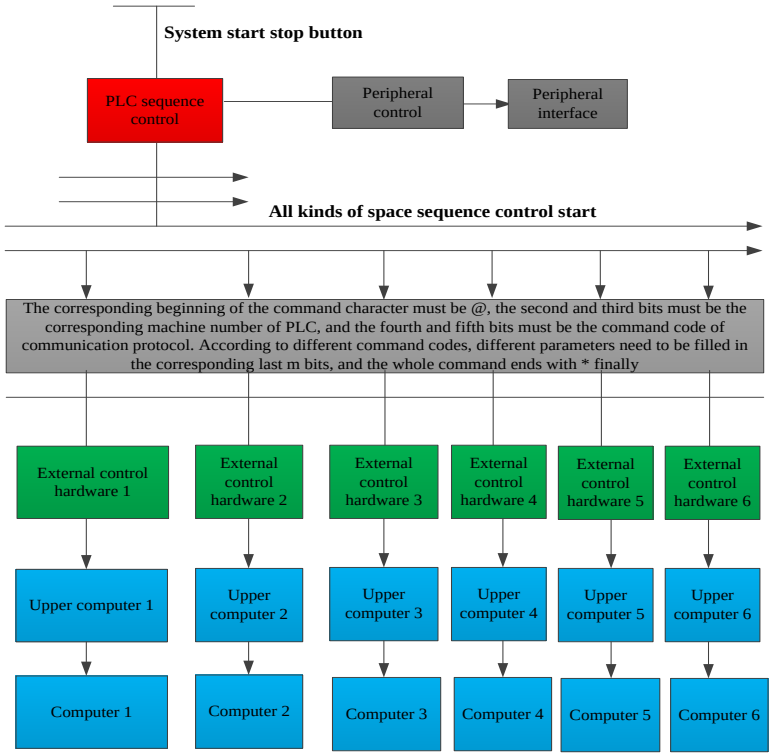

Figure 2: PLC sequence control communication architecture under computer assistance.

It can be seen from Figure 2 that when the whole system uses the communication protocol to work, the corresponding host computer sends the corresponding PLC command characters and phase. The command string returned to the host computer by the corresponding PLC has corresponding restrictions on the corresponding string degree, and the corresponding string length is limited to less than 13 characters. In terms of the corresponding data format requirements of the corresponding communication protocol, the corresponding protocol of the system has clear and strict requirements. As can be seen from Figure 2, the corresponding beginning of the command character sent by the upper computer through the corresponding serial port or network interface must be" @", and the corresponding adjacent second and third digits must be the corresponding machine number of PLC, and the corresponding fourth and fifth digits must be "@" .According to different command codes, different parameters need to be filled in the last m bits of the

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

corresponding command codes, and the whole command ends with "*". In the corresponding whole system, the data format of PLC responding to the instruction sent by the upper computer is basically consistent with that of the upper computer. The difference is that the last two characters corresponding to the responding command characters are the corresponding execution status codes.

At the corresponding communication level between computer and PLC, the system mainly carries out serial communication based on serial port class processing interface, and the corresponding communication driver algorithm is set as event driven algorithm. The event driven algorithm is mainly realized by the computer monitoring operating system to monitor the serial port. In essence, it does not need to monitor the serial port in fact, thus saving the corresponding CPU resources. The corresponding mainstream code program is shown in Figure 3, and the corresponding key function includes serial port_ Datareceived and some class functions. Figure 3 also shows the core code that the corresponding PLC in the control system reads data from the system communication protocol. In the displayed code, the PLC reads the data function of the specified starting bit and the corresponding length in time after sending the operation instruction. The corresponding macno in the corresponding code represents the machine number in the industrial control system, and the corresponding order represents the corresponding instruction sending, corresponding to Adress represents the starting address of the corresponding PLC data, long represents the length of the data read out by PLC, and result represents the data result read out by system PLC.

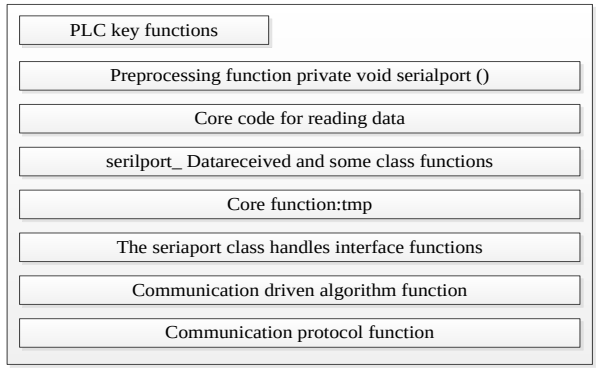

Figure 3: Core code of serial communication between computer and PLC in control system.

Based on the above analysis and research, the host link serial communication technology protocol corresponding to the PLC control system under the computer assistance can well realize the serial communication between the computer and PLC. At the same time, this section also profoundly reveals the data format and operation mode of the corresponding commands sent by the computer to the PLC and returned by the PLC to the computer in the whole industrial control system. Overall, host link serial communication protocol has obvious communication effect and operation advantages.

2.2 Architecture Analysis of PLC Control System Aided by Computer

In order to be more compatible with the programming environment of computer and PLC system, and to be close to the programming environment of computer to the greatest extent, the corresponding programming language is closer to the natural language, so that the corresponding developers and readers can better understand the programming language. At the same time, the corresponding programming language has higher reusability and better scalability. The system architecture of PLC industrial control system designed in this paper is shown in Figure 4. It can be seen from Figure 4 that the classification of PLC control system is fully considered when designing

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

the architecture, and the functions of corresponding PLC control system are mapped to corresponding functions.

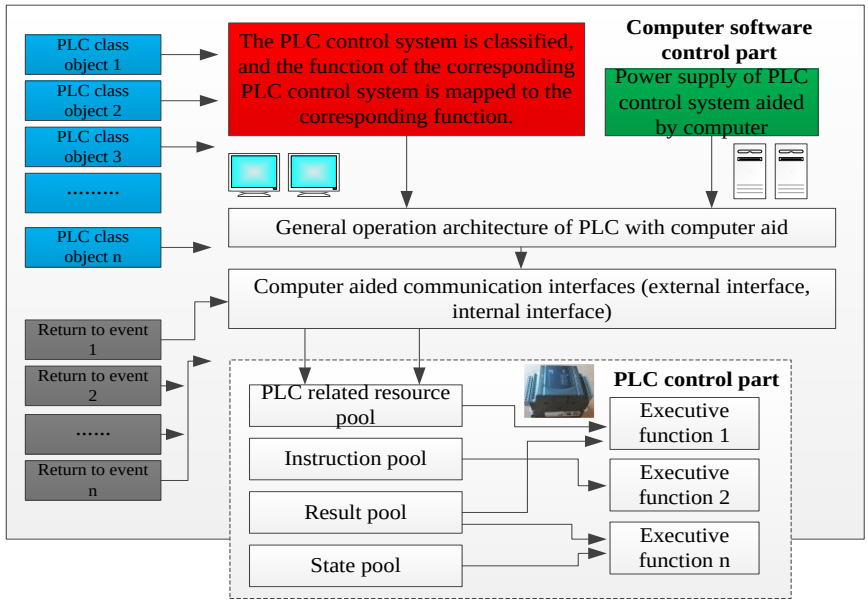

Figure 4: Architecture of PLC industrial control system with computer aid.

After the relevant sequence control instructions are finished, the computer will automatically generate the corresponding control instructions and send them to the PLC for simplified processing. The corresponding PLC control system only performs the calculation as an actuator The simple instructions sent by the computer, the corresponding simple operation instructions include: data memory read-write, timing and counting functions, and the corresponding switch on and off functions. In the actual computer-aided PLC control system operation, the corresponding computer control program and PLC hardware controller constitute the key to the whole system operation, and the corresponding system successful operation mechanism is shown in Figure 5. From Figure 5, we can see that the operation process is as follows: first, continuously search the PLC hardware in the system connected to the computer, and at the same time, the corresponding hardware In order to register, the corresponding data memory of the corresponding PLC hardware in the system is mainly used to store the specific address and related hardware information. The computer sends the serial port instruction through the running program or contacts the related PLC hardware through the associated network, and reads the corresponding hardware information and registration information from it. At the same time, it realizes the monitoring function of PLC running The corresponding PLC hardware in the system accepts the commands from different PLC hardware objects, and constructs the corresponding commands in real time to return to the registered PLC hardware instruction pool; the system realizes the realization of the control commands, and the corresponding control commands include the sending return control, error command control, conflict command control and lock control; the PLC hardware in the corresponding registered system can be transferred to the PLC hardware instruction pool In the instruction pool, read the corresponding running state and return value, and then process and analyze, then call the corresponding callback function in the PLC instance corresponding to the execution signal.

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

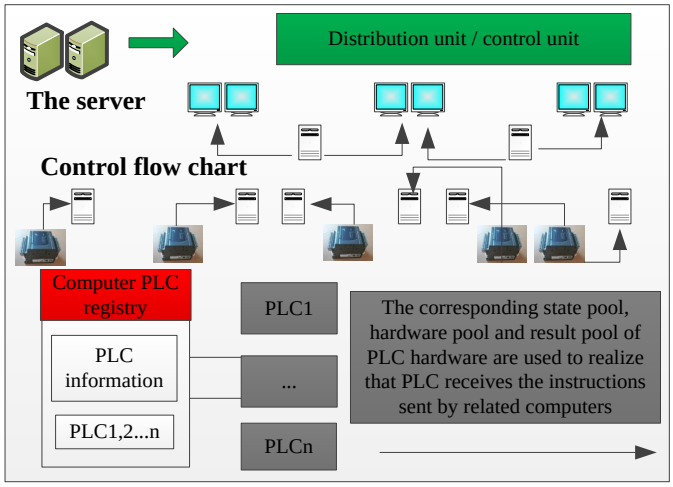

Figure 5: The frame diagram of PLC industrial control system operation mechanism under computer assistance.

The corresponding state pool, hardware pool and result pool of the corresponding PLC hardware in the system are used to realize the PLC receiving the instructions sent by the relevant computer. The corresponding computer in the corresponding industrial control system constantly reads and writes the corresponding contents of the state pool, hardware pool and result pool in the PLC hardware system to realize the real-time control of the hardware PLC operation status, and the corresponding P The LC hardware system also realizes the corresponding commands by reading and writing the corresponding three areas. In the corresponding PLC hardware control system, its internal code is executed from top to bottom, and it is executed continuously from left to right. The computer-aided PLC control system strictly requires the PLC hardware to strictly execute the internal program once, and the state pool must be checked once at the same time.

3 EXPERIMENTAL ANALYSIS OF PLC CONTROL SYSTEM WITH COMPUTER AID

Based on the above-mentioned architecture design of PLC industrial control system under computer-aided control, this paper will carry out experiments based on a certain air pressure control industrial control system and analyze the corresponding experimental data.

3.1 Experiment of Traditional Pneumatic Control Circuit based on PLC Control System Aided by Computer

In the corresponding air pressure control system, we mainly focus on the sequence control of the cylinder, pneumatic claw and other related hardware, and number the corresponding cylinder and the auxiliary detection elements of the pneumatic claw. The auxiliary elements of the pneumatic claw corresponding to the air pressure control system verified in this paper are numbered as A1, A2, A3, A4, A5, A6 and A7, and the corresponding sequence programming partition of the pneumatic transmission circuit is shown in Figure 6 The main action process of the system includes: the cylinder in the system extends - the cylinder in the system compresses - the system delays the corresponding time - the system compresses the corresponding air claw - the system realizes the corresponding time delay - the system relaxes the corresponding air claw.

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

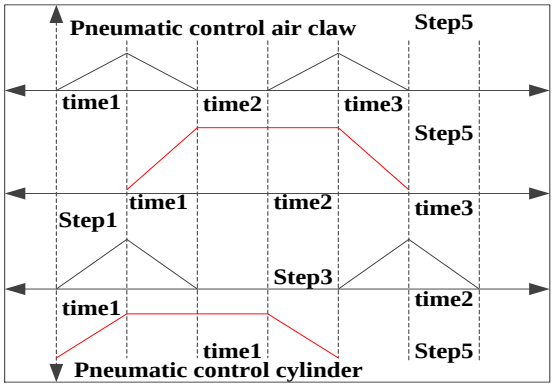

Figure 6: Sequence programming partition diagram of pneumatic transmission circuit of PLC control system aided by computer.

Based on the above partition, according to the sequence control of the pneumatic system loop under the shift command, the computer programming is carried out, in which the corresponding number of the executive elements and the corresponding time sequence of the detection elements are processed, and the corresponding processing flow chart is shown in Figure 7, which fully shows the corresponding time sequence mode of the cylinder and the corresponding air claw auxiliary elements.

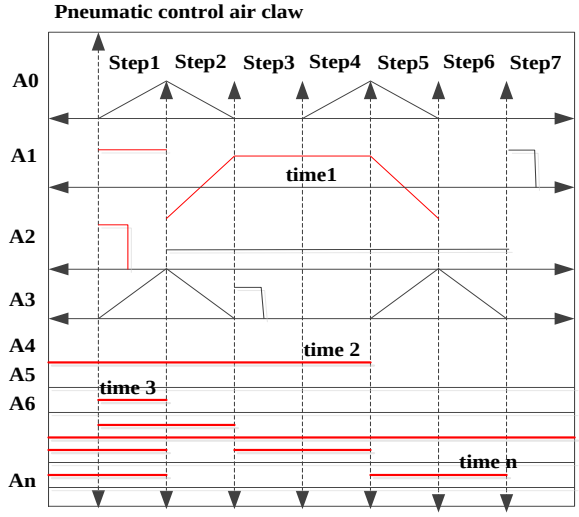

Figure 7: Time sequence mode diagram of air pressure control auxiliary components of PLC control system aided by computer.

Based on the analysis of the above-mentioned time sequence, the structure of the air pressure control program in the system is designed. After the air pressure control system in this paper is manually pressed to perform the operation, the corresponding control system will run the corresponding normal action according to the sequence control, and repeat the operation cycle by cycle. The corresponding control program flow chart is shown in Figure 8, and the corresponding action sequence diagram is also shown in Figure 8. It can be seen from the figure that the program mode designed in this paper is automatic circulation mode.

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

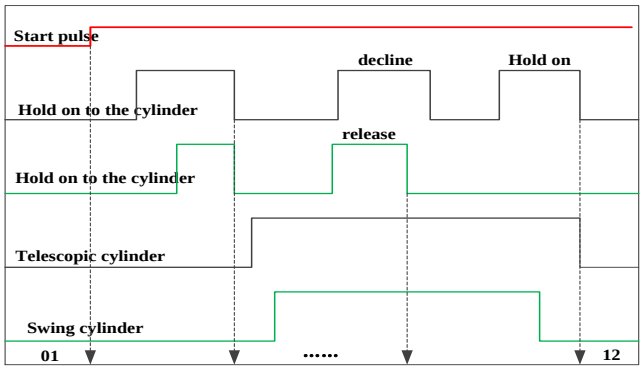

Figure 8: Flow chart of control program of computer PLC control system in air pressure control system.

3.2 Analysis of Experimental Results

In order to compare the advantages and disadvantages of the design scheme and the traditional pneumatic control system, the following two indicators are used for evaluation and comparative analysis, which correspond to: the corresponding control system resource consumption degree and system operation failure rate under the same operation.

Result analysis of Comparative Experiment 1: under two different control systems, the air pressure control system runs the same work. At this time, the corresponding resource consumption of the control system is calculated, and the corresponding consumption results are shown in Figure 9.

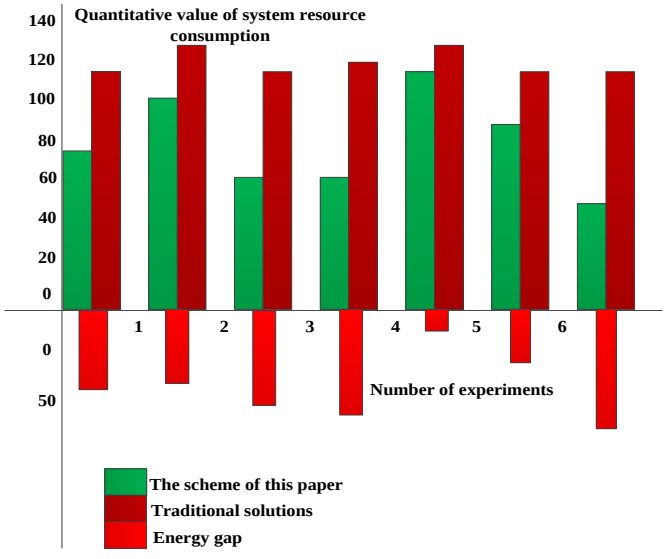

Figure 9: Comparison Chart of corresponding scheme consumption under control variables.

As can be seen from Figure 9, in the case of control variables, the corresponding resource consumption of PLC control system in this paper is less, and its corresponding execution efficiency is higher. Because all the control and execution of traditional control system depend on PLC hardware, it has higher requirements on PLC hardware performance, and its corresponding resource consumption is also higher.

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

Analysis of the results of Comparative Experiment 2: make the air pressure control system run the same work under two different control systems. At this time, pay attention to the operation failure rate of the air pressure control system, and the corresponding failure rate results are shown in Figure 10. As can be seen from Figure 10, in the case of control variables, the corresponding failure rate of the computer-aided PLC control system is lower, and its corresponding execution efficiency is higher. At the same time, from the corresponding curve trend, it can be seen that with the passage of time, the lower the failure rate of the proposed scheme, the more obvious its advantages.

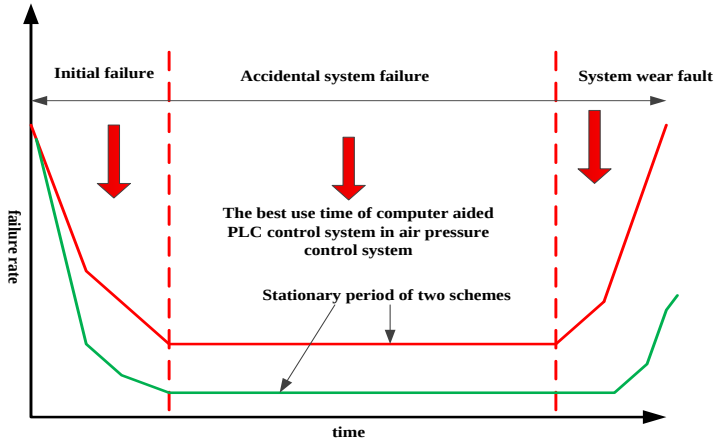

Figure 10: comparison of failure rate of corresponding scheme control system under control variables.

4 CONCLUSIONS

This paper mainly analyzes the current industrial control field of PLC control system principle and the corresponding research status, and gives the disadvantages of the current traditional computer-aided PLC control system. Based on this drawback, in order to solve the problem of compatibility and development difficulty of PLC control system under the assistance of calculation, this paper uses the air pressure control system of pneumatic transmission equipment as the carrier, develops the system level of PLC control system under the object-oriented computer assistance, and designs the overall architecture of PLC control system under the assistance of computer At the same time, the operation mechanism of the architecture is described in detail. In the experiment part, the traditional air pressure control circuit is reformed and designed based on the PLC control system under the computer assistance, and the sequence control program suitable for its use is proposed. Finally, the experimental verification analysis is carried out based on the control system proposed in this paper. The experimental results show that the design scheme and the corresponding sequence control algorithm proposed in this paper are more reasonable than the traditional scheme, and the same as the traditional scheme It also verifies that the corresponding program runs safely and reliably, and the corresponding scalability also has certain advantages.

5 ACKNOWLEDGEMENTS

Soft Science Research Project of 2021 Science and Technology Development Plan of Henan Science and Technology Department: Research on Methods and Approaches of Building New Knowledge Competence of Scientific and Technical Talents in Higher Vocational Colleges Based on AI Technology (NO.212400410187).

© 2022 CAD Solutions, LLC, http://www.cad-journal.net

Cunzhi Yao, https://orcid.org/0000-0003-1605-564X
Yingjie Wang, https://orcid.org/0000-0002-6774-5862

REFERENCES

[1] Telang, A.-S.: Systematic approach towards computer aided non-linear control system analysis using describing function models, Machine Learning Research, 4(1), 2019, 13. https://doi.org/10.11648/j.mlr.20190401.13
[2] Krystek, J.; Alszer, S.; Bysko, S.: Computer aided design of sequencing problem–the concept of Paint Shop 4.0, Mechanik, 91(7), 2018, 529-531. https://orcid.org/0000-0003-2015-3453
[3] Radhi Mahmood, J.; Salim Ali, R.; Abd-Alhameed, R.-A.: PLC/HMI-Based Implementation of a Real-Time Educational Power System Protective Relays Platform, Electronics, 9(1), 2020, 118-118. https://doi.org/10.3390/electronics9010118
[4] Kiedrowski, P.; Marciniak, T.; Lutowski, Z.; Zabłudowski, Ł.: Effectiveness of BPSK modulation with peak noise avoidance algorithm in smart street lighting communications based on PLC, Image Processing & Communications, 23(1), 2018, 5-10. https://doi.org/10.1515/ipc-2018-0001
[5] Sutisna, N.-A.; Firmansyah, R.-A.: Design of Automatic Stamping Machine For Date And Dash Code Marking Using Pneumatic System And Plc Controller, Journal of Mechanical Engineering and Mechatronics, 3(1), 2019, 40-49. http://dx.doi.org/10.33021/jmem.v3i1.536
[6] Fujisawa, T.; Yamashita, Y.; Sakamoto, T.; Matsui, T.; Tsujikawa, K.; Nakajima, K.; Saitoh, K.: Scrambling-type three-mode PLC multiplexer based on cascaded Y-branch waveguide with integrated mode rotator, Journal of Lightwave Technology, 36(10), 2018, 1985-1992. https://www.osapublishing.org/jlt/abstract.cfm?uri=jlt-36-10-1985
[7] Eguti, C.-C.-A.; Trabasso, L.-G.: The virtual commissioning technology applied in the design process of a flexible automation system, Journal of the Brazilian Society of Mechanical Sciences and Engineering, 40(8), 2018, 1-12. https://doi.org/10.1007/s40430-018-1322-2
[8] Otte, J.-N.; Kiritsi, D.; Ali, M.-M.; Yang, R.; Zhang, B.; Rudnicki, R.; Smith, B.: An ontological approach to representing the product life cycle, Applied Ontology, 14(2), 2019, 179-197. https://doi.org/10.3233/AO-190210
[9] Bibikov, S.-V.; Bolshakov, V.-O.; Kalinkina, M.-E.; Korobeynikov, A.-G.; Tkalich, V.-L.: Development of computer-aided design system of sensitive elements of control and automation systems, Journal of Physics Conference Series, 1333, 2019, 082005. https://doi.org/10.1088/1742-6596/1333/8/082005
[10] Khan, M.-T.-H.; Demoly, F.; Kim, K.-Y.: Constructing assembly design model capable of capturing and sharing semantic dynamic motion information in heterogeneous CAD systems, The International Journal of Advanced Manufacturing Technology, 111(3), 2020, 945-961. https://doi.org/10.1007/s00170-020-06046-7

© 2022 CAD Solutions, LLC, http://www.cad-journal.net