THE USE OF GENETIC ALGORITHM IN THE DESIGN OF INTERNET OF THINGS PLATFORM OF HEAT ENERGY COLLECTION SYSTEM

by

Jiangang JIN*

School of Information Engineering,
North China University of Water Resource and Electric Power, Zhengzhou, Henan, China

Original scientific paper
https://doi.org/10.2298/TSCI191113108J

Objective: The application of genetic algorithm in the design of the Internet of Things platform of heat energy collection system is launched, and the value of the application of the Internet of Things control platform of genetic algorithm in the heat energy collection system is analyzed to verify its effectiveness and superiority. Method: Firstly, the design of the basic framework of the Internet of Things is developed, mainly on the acquisition and processing module and the communication module of the framework. Then, genetic algorithm is used to make statistics of the system nodes in the heat energy collection system, and establish the optimization function of heat energy conversion rate based on genetic algorithm. Then, the optimization function is used to design the control circuit to improve the flexibility of the control circuit. Finally, the system developed in this study is verified by experiments. Results: After the application of three platforms to control the heat energy collection system, the heat energy conversion rate is higher than that of the previous platform, and the platform controlled thermal energy conversion rate is the highest. Moreover, the real-time energy consumption is the smallest. Conclusion: It is found that the application of genetic algorithm in the Internet of Things platform of the heat energy collection system can effectively optimize the heat energy conversion rate, and the real-time work energy consumption is also very low, which improves the heat energy standardization rate, has certain application value, and can better improve the energy source rate.

Key words: *genetic algorithm, heat energy collection system, Internet of Things, heat energy conversion rate*

Introduction

In order to effectively reduce heating energy consumption, improve energy efficiency, and promote behavior energy conservation, the state actively promotes the thermal measurement transformation project of public institutions, including the transformation of thermal measurement equipment at the building end of public institutions and the construction of real-time monitoring platform for energy consumption based on Internet of Things (IoT) technology by management departments. Through the transformation of thermal measurement lines and equipment and climate compensation technology, the flow of each heating building is dynamically balanced, and the room temperature is adjusted and balanced. The indoor heating environment

* Author's e-mail: hn_jjg@126.com

quality is improved, and at the same time, the consumption of heat energy in the transition is effectively avoided [1, 2]. On the other hand, based on the IoT technology, the heat metering data at the building end is collected to the energy consumption management organization in real time, which can intuitively and real-time monitor the actual energy consumption status of each energy consumption unit and the intactness of metering and control equipment, realize the information balance between the regulatory authority and the energy consumption unit, and ensure that the metering facilities are in good condition and in the optimal energy-saving state, and excessive energy consumption and failure equipment can be warned in time. Through on-line real-time interaction with room temperature control equipment, active time-division temperature control, time-division heating and time-division heat preservation can be realized [3, 4]. In addition, relying on the platform to process, analyze and graphically display energy consumption data, the summary statistical analysis results of energy consumption data can be released at any time, so as to provide policy, constructive and scientific guidance for the management department to adjust energy conservation policies and models. While analyzing the effect of the implementation of the thermal metering transformation project, formulating energy conservation and emission reduction policies, providing efficient, easy-to-use and advanced means for the management department, the comprehensive goal of strengthening the energy consumption management of public institutions, improving the level of energy conservation operation management, and improving the awareness of energy conservation of the whole region's public behavior is achieved [5-7].

With the advantages of low consumption and environmental protection, heat energy collection system has been widely used in electric power, machinery, electronics and other fields [8-10]. In order to further improve the heat energy conversion rate of the heat energy collection system, the control platform of the IoT of the heat energy collection system will generate [11, 12]. The control platform of the IoT has the advantages of low cost, good control effect and simple control process, which is a common control implementation scheme [13]. However, the selection of the IoT basic framework is so much that the energy consumption of the IoT control platform of the heat energy collection system is high, and the heat energy conversion rate of the heat energy collection system cannot be effectively improved [14]. For this reason, scientific research organizations are committed to designing a control platform of the IoT with low energy consumption and strong ability to improve the thermal energy conversion rate of the thermal energy collection system. Previous researchers designed the control platform of the IoT based on the extreme dynamic programming. This platform focuses on the extreme dynamic programming with low energy consumption, and uses it in the IoT control platform to improve the heat energy conversion rate of the heat energy collection system. However, extreme dynamic programming is more complex and requires more time and money.

In this study, the control platform of the IoT is designed and developed by applying genetic algorithm to the heat energy collection system. The acquisition and processing module and communication module in the framework system are developed and designed. Then, the genetic algorithm is applied to establish the thermal energy conversion optimization function, which is applied to the control circuit. Finally, the comparative experiments of heat energy conversion rate of three different platforms are carried out to verify the effectiveness and superiority of genetic algorithm in the design of the IoT platform of heat energy collection system. Experiments show that the control platform based on genetic algorithm can effectively reduce the energy consumption of the system, and also can improve the thermal energy conversion rate of the thermal energy collection system. This study is of great significance to the development and reuse of energy and energy conservation management.

Method

Design of IoT basic framework

In this experiment, genetic algorithm is applied to design the basic framework of the IoT. The application of genetic algorithm can effectively reduce and optimize the energy consumption of the platform, and can further provide the basic hardware support for the control end of the IoT. The heat collection system and the IoT control platform can be connected. Among them, the main function of the basic framework of the IoT is to collect and process the thermal data in the thermal energy collection system, and can effectively link and interact the data of the thermal energy collection system and the network. In this study, the framework of the IoT system is mainly designed from the construction of two modules.

Acquisition and processing module

The hardware structure of the IoT acquisition and processing module is shown in fig. 1. When designing the basic framework of the IoT, WMNBM14s and STM32F103 are used as the core hardware. Each hardware plays a different role. Among them, WMNBM14s chip is used to collect the data and information in the thermal data system, and is responsible for connecting the communication modules in the processing module. The main function of STM32F103 is to process the data and information in the thermal data system. In the design of the whole module, the working energy consumption of the applied components is relatively low, which can meet the requirements of the initial design. In the figure, it can be seen that WMNBM14s chip is connected with thermal energy collection system and communication module by using asynchronous transceiver. The WMNBM14s chip and STM32F103 chip are connected through serial peripheral interface (SPI). The SPI, as a communication interface, has the nature of full-duplex. Through this interface, the two chips are connected with each other and the data transmitted by each other are read and called. Among them, STM32F103 chip can effectively analyze, disassemble and process the data, which is not only efficient, but also relatively low energy consumption. This chip will transmit data and information the communication module through WMNBM14s chip.

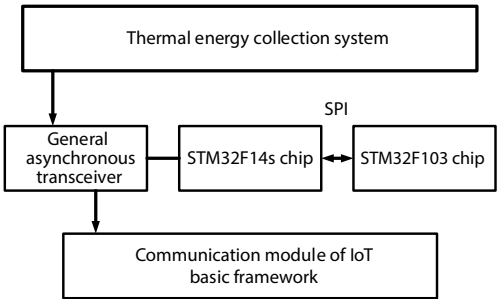

Figure 1. Structure of acquisition and processing module

Communication module

In this study, the main function of the communication module is to transmit the data processing results of the collection and processing module to the control end of the IoT, and then feedback the results through the control instructions. This kind of feedback has a direct nature, and there is no need for other auxiliary methods or tools. The ultimate goal of feedback is the controlled area of the thermal energy collection system. As can be seen from fig. 2, in the process of designing communication module, BCM43362 wireless chip is mainly used as the core element of communication module. The supporting components of communication module mainly include user node, software development kit and core firewall, which can help BCM43362 wireless chip and communication control protocol. The main advantages of this chip are good compatibility and stability, relatively less energy consumption, and can well

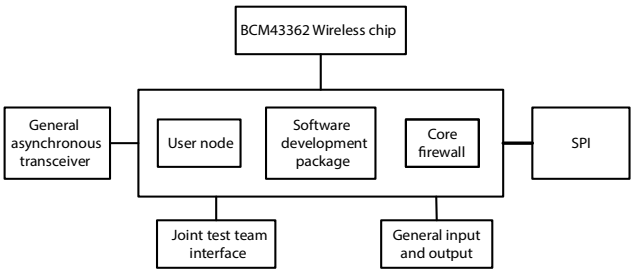

Figure 2. Structure of communication module

handle the complex communication work. Among them, the communication support component mainly has four different communication interfaces, which can help reduce the working pressure of the chip, avoid the chip thermal damage, and also effectively reduce the energy consumption of the communication module.

Design of IoT control terminal

In this study, when designing the control end of the IoT, the main optimization algorithm is genetic algorithm. The main function of genetic algorithm is to optimize the thermal energy conversion rate. The main principle is to input the optimization function of heat energy conversion rate of genetic algorithm and the result of heat energy data processing into the control circuit at the same time. After that, the control instructions in the control circuit are made. The basic framework of the IoT will provide further feedback on control instructions. The final feedback destination is to the controlled area of the thermal energy collection system.

Optimization function of heat energy conversion rate based on genetic algorithm

In this study, by following the basic steps and using the advantage constraint heat energy collection system of genetic algorithm, the heat energy conversion rate is optimized.

Firstly, genetic algorithm is applied to the statistics of system nodes in the heat energy collection system. The main characteristic of this kind of system node is to affect the thermal energy conversion rate of the system, which will cause the conversion rate of the system to be too low. Therefore, in this experiment, the optimization set of thermal energy is constructed and represented by max*f*:

$$\max f = [f_1(x) f_2(x) ... f_n(x)] \tag{1}$$

The system node is represented by $f_n(x)$. A system node in the equation is taken as the key objective of this optimization. In the research, in order to make the genetic algorithm can effectively optimize the overall control performance of the control platform of the IoT of the heat energy collection system, the threshold F of the key optimization project should meet:

$$0.9 < F < 1 \tag{2}$$

The P_{on} is used to express the real-time thermal energy conversion rate of F. Then, the system nodes in the key optimization project are taken as the center points. The remaining $n - 1$ system nodes in maxf are arranged in order around the center of the circle. The effective nodes in the system are represented by m. When the thermal energy collection system is working, the nodes in the process of thermal energy conversion are represented by k. Then, genetic algorithm is applied to optimize the thermal energy conversion rate:

$$\max\left(0, \frac{k-10}{m}\right) < P_{on} < \min\left(1, \frac{K+10}{m}\right) \tag{3}$$

By inputting the optimization functions of the aforementioned three genetic algorithms into the heat energy collection system, the heat energy data can be optimized reasonably and effectively.

Design of control circuit

In this experiment, the control circuit is designed. Each controlled area of the heat energy collection system has its own control scheme, so it has high requirements for the control circuit, which requires a lot of flexibility. Only with high flexibility can different types of thermal data be analyzed and processed. After analyzing the data, according to the previous analysis results, the control instructions of the system are reasonably formulated. The control circuit designed for the system is shown in the fig. 3. According to the fig. 3, the four interfaces in the IoT communication module will be connected with the interfaces in the control circuit. This connection method can classify the data information after processing and parsing. Through classification, the workload of system analysis can be reduced, so that the efficiency of system analysis can be improved. After classification, the data will be collected together, and then further enlarged to complete the analysis work. The optimization function of the thermal energy conversion rate of the genetic algorithm applied in this study will reach the function generator through the interface of the working group. Then, the functional converter will complete the optimization of the thermal converter. The control circuit will give the control instructions of each corresponding area according to the completed optimization results. Then, the reverse amplifier will further reduce the signal of the control command to the original state. After that, the asynchronous transmitter is used to transmit the signal to the communication module in the IoT. The last step is to use the controlled area of the system to control the signal information.

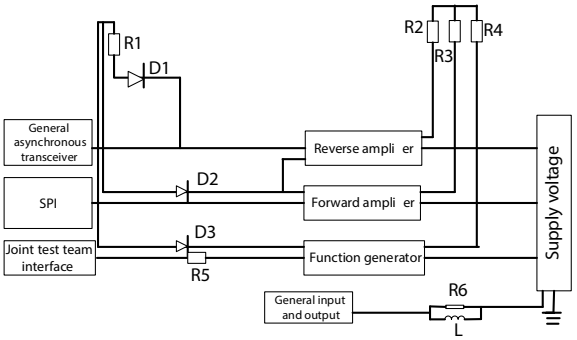

Figure 3. Control circuit

Experimental analysis results

In this study, the verification of the research system is completed through experiments. Through the application of the platform of this experiment, Scrum platform and extreme static programming platform, the control of the IoT is completed for the heat energy collection system. The weather is suitable for the experiment. From 10 a. m. to 3 p. m. there is always sunlight on the heat collection system.

In this study, firstly, under the condition of no application of any platform, the solar thermal energy is collected by the thermal energy collection system. In the process of experiment collection, the temperature and humidity of the laboratory need to be adjusted in real time. The time is every other hour, and a total of five times of collection are carried out. Among them, the temperature is 23 °C, 25 °C, 27 °C, 29 °C, and 32°C, respectively. The humidity is 43% RH, 52% RH, 58% RH, 61% RH, and 68% RH, respectively. The heat energy conversion results of the collected heat energy system are shown in the fig. 4.

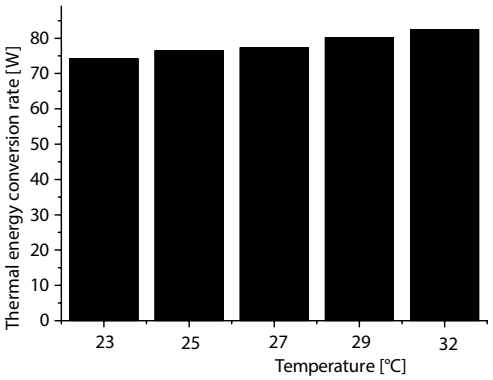

Figure 4. Thermal energy conversion rate without platform control

As can be seen from the previous figure, without using any platform, with the increase of temperature and humidity, the thermal energy conversion rate of the thermal energy collection system will be higher and higher. When the temperature is 32 °C and the humidity is 68% RH, the thermal energy conversion rate is the highest, 82.5%.

In this experiment, by using the platform of the research, Scrum platform and extreme static programming platform, the heat energy collection system in the experiment is controlled by the IoT. The results of the thermal energy conversion rate of the thermal energy collection system after the application platform control are shown in the fig. 5.

From the fig. 6, it can be seen that after the application of three platforms to control the heat energy collection system, it is found that the heat energy conversion rate is higher than the heat energy conversion rate controlled by the previous platform, which has been greatly improved, about 90% higher than the previous platform. However, among these three platforms, in this study, the thermal energy conversion rate controlled by the platform in this study is the highest. At 32 °C, the thermal energy conversion rate is 96.7%, which is the most effective and superior.

According to fig. 7, the real-time working energy consumption of these three platforms is on the rise. Among them, the real-time energy consumption of the extreme static programming platform is the largest, followed by the Scrum platform. However, the real-time energy consumption of the control platform based on genetic algorithm is the lowest. It can be seen that the control platform of the IoT based on genetic algorithm can save energy very well, and has a wide range of application value.

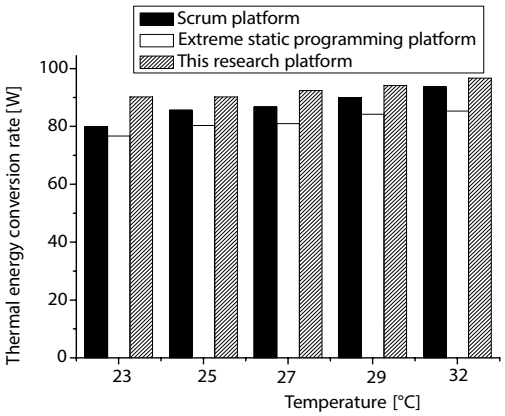

Figure 5. Thermal energy conversion rate after application of control platform

Discussion

The emergence and development of heat energy collection system effectively reduces the loss of energy and promotes the development of environmental protection in China.

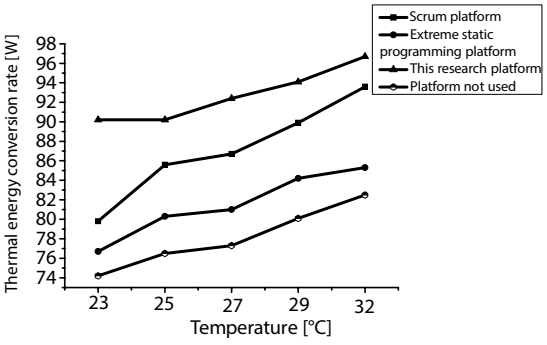

Figure 6. Trend chart of thermal energy conversion rate after application of control platform and before application

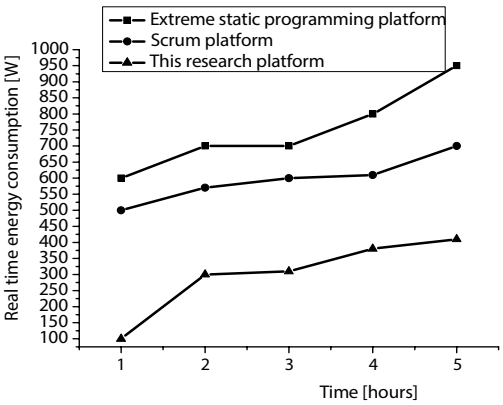

Figure 7. Real time energy consumption of three platforms

Now, because of its unique quality, the heat energy collection system has been applied in various industries and fields. The application of the IoT control platform can effectively reduce energy consumption and promote the realization of the system work. This year, the application of IoT control platform is more and more extensive, but there are also many shortcomings. The selectivity of its basic framework is relatively large, which leads to the high energy consumption of the IoT control platform of the heat energy collection system, and cannot effectively improve the heat energy conversion rate of the heat energy collection system. Therefore, it is very important to study the new control system of the IoT.

Based on this, in this study, the control platform of the IoT based on genetic algorithm is designed. The WMNBM14s and STM32F103 are used in the infrastructure of the IoT platform to collect and process the thermal data collected in the thermal energy collection system. Then, the control circuit is used to classify and analyze the data processing results, and optimize the conversion rate of the thermal energy, and then send out the control instructions to the corresponding control area. Through the wireless chip BCM43362, the sustainable and efficient control of the controlled object can be realized. The experimental results show that, without using any platform, the heat energy conversion rate of the heat energy collection system will be higher and higher with the increase of temperature and humidity. After the application of three platforms to control the heat energy collection system, the heat energy conversion rate is higher than that of the previous platform, which is about 90% higher than that of the previous platform. The thermal energy conversion rate of the platform is the highest and the real-time energy consumption is the smallest. The results show that the energy consumption of the platform is low, and the efficiency of the heat energy conversion and collection system can be significantly improved.

Conclusion

Applying genetic algorithm to the control platform of the IoT can improve the heat energy conversion rate of the heat energy collection system, and the real-time energy consumption is also very small. The system developed in this study is compared with the other two systems, and it is found that the control platform of the IoT based on genetic algorithm has certain effectiveness and superiority, which can be widely used in the thermal energy collection system. However, in this study, in the development and design of the control system, only from the two aspects of communication module and acquisition and processing module, only the genetic algorithm is applied to the control circuit of the IoT control terminal, without considering the whole system. Moreover, only one optimization algorithm is applied. In the future research, it is necessary to give full play to the role of genetic algorithm, combined with other optimization algorithms, to further improve the control performance of the system.

References

[1] Edoardo, P., *et al.*, Genetic-Algorithm Based Method for Mitigating Label Noise Issue in ECG Signal Classification, *Biomedical Signal Processing and Control*, *19* (2015), May, pp. 130-136
[2] Jayanthi, S., *et al*., Internet of Things (IOT) Based Generous Transformational Optimization Algorithm (GTOA) for Hybrid Renewable Energy System Synchronization and Status Monitioring, *Wireless Personal Communications*, *102* (2018), 4, pp. 2597-2618
[3] Shaofei, W., Study and Evaluation of Clustering Algorithm for Solubility and Thermodynamic Data of Glycerol Derivatives, *Thermal Science*, *23* (2019), 5, pp. 2867-2875
[4] Li, J., *et al*., Magnetotelluric Noise Suppression Based on Matching Pursuit and Genetic Algorithm, *Chinese Journal of Geophysics- Chinese Edition*, *61* (2018), 7, pp. 3086-3101
[5] Enji, S., Internet of Things Based Combustible Ice Safety Monitoring System Framework, *IOP Conference Series Earth and Environmental Science*, *63* (2017), 1, 012001

[6] Vigneswaran, V. S., *et al*., Performance Evaluation of Solar Box Cooker Assisted with Latent Heat Energy Storage System for Cooking Application, *Iop Conference*, *67* (2017), 1, 012017
[7] Qie, S., *et al.*, A Comprehensive Review of Smart Energy Meters in Intelligent Energy Networks, *IEEE Internet of Things Journal*, *3* (2015), 4, pp. 464-479
[8] Xiaolong, X., *et al*., CLOTHO: A Large-Scale Internet of Things based Crowd Evacuation Planning System for Disaster Management. *IEEE Internet of Things Journal*, *5* (2018), 5, pp. 3559-3568
[9] Mianxiong, D., *et al*., RMER: Reliable and Energy-Efficient Data Collection for Large-Scale Wireless Sensor Networks, *IEEE Internet of Things Journal*, *3* (2017), 4, pp. 511-519
[10] Shaofei, W., *et al*., Bidirectional Cognitive Computing Method Supported by Cloud Technology, *Cognitive Systems Research*, *52* (2018), Dec., pp. 615-621
[11] Yuxin, L., *et al*., FFSC: An Energy Efficiency Communications Approach for Delay Minimizing in Internet of Things, *IEEE Access*, *4* (2017), July, pp. 3775-3793
[12] Saleem, A., *et al*., Energy and Spectral Efficient Cognitive Radio Sensor Networks for Internet of Things, *IEEE Internet of Things Journal*, *5* (2018), 4, pp. 3220-3233
[13] Chang, Z. S., *et al*., A Framework for Incorporating Demand Response of Smart Buildings into the Integrated Heat and Electricity Energy System, *IEEE Transactions on Industrial Electronics*, *66* (2017), 2, pp. 1465-1475
[14] Xiong, L., *et al*., A Robust and Energy Efficient Authentication Protocol for Industrial Internet of Things, *IEEE Internet of Things Journal*, *5* (2017), 3, pp. 1606-1615

Paper submitted: November 13, 2019
Paper revised: December 22, 2019
Paper accepted: January 13, 2020