International Journal for Housing Science and Its Applications
Publish August 10, 2025. Volume 46, Issue 4 Pages 7211-7224

https://doi.org/10.70517/ijhsa464625

Research on the control technology of energy-saving and emission reduction electrical automation system for intelligent buildings

Jin Zhang[1,*]
[1] Changzhou College of Information Technology, Changzhou, Jiangsu, 213164, China
Corresponding authors: (e-mail: wsqgdyzjcgpszc@163.com).

Abstract The construction industry, as one of the industries of environmental pollution, especially needs to pay attention to energy saving and emission reduction and sustainable development. This paper combines the actual construction project profile, the energy saving and emission reduction electrical automation system design under the concept of intelligent building, and then use BP neural network to construct the energy emission reduction electrical automation system energy consumption prediction model, and in this way to guide the system scheduling and control work for the development of the system control program to provide a scientific decision-making basis. Starting from the actual development of the current intelligent building, selecting the power consumption, carbon emissions, system operation and management costs as the objective function, while also setting the constraints, and proposing the use of genetic algorithms to form the system scheduling control model. Finally, based on the system energy consumption prediction and control, the research program of this paper is empirically analyzed. The genetic algorithm calculates the optimal solution of the three objective functions as 4821KJ, 21.81t, 100,600 yuan, respectively, i.e., the genetic algorithm realizes the globally optimal energy-saving and emission reduction electrical automation system control. In this paper, the role of the control program, energy saving power 28710.5kW·h, converted into carbon dioxide emissions of 30.415t, comprehensively confirmed the system control of this paper has a good practical effect.

Index Terms intelligent building, sustainable development, energy saving and emission reduction, BP neural network, genetic algorithm

I. Introduction

Accompanied by the continuous expansion of China's urban construction scale, urban intelligent buildings more and more, more and more complex, which requires that there must be a sufficient amount of energy as a support [1], [2]. Urban intelligent buildings on the huge consumption of energy use, China's carbon emissions and other targets is a serious test, how to ensure that the normal use of urban development with adequate energy supply, is the whole society, the industry are faced with a serious test, which is aimed at the intelligent building electrical automation technology for the control of energy consumption requirements appear to be very strict and necessary [3]-[6].

Intelligent building is to realize the optimization of building structure and equipment, services, management to meet the needs of the residents of the integrated, its purpose is to provide users with a comfortable, safe, efficient, convenient humanized building environment, the emergence of intelligent buildings not only improves the energy-saving level of the building and the efficiency of the use of space, but also improves the quality of people's lives and security [7]-[10]. Electrical automation control technology is an important research field in the current intelligent building industry, which is the foundation and platform for building intelligent buildings, and it realizes the automated management and optimized regulation of building electrical equipment through the introduction of advanced intelligent control technology and energy-saving equipment [11]-[14]. Thus, it improves energy utilization efficiency, reduces energy consumption and operating costs, reduces environmental pollution, promotes building energy conservation and emission reduction, and is an indispensable part of intelligent buildings [15]-[17]. From the automation control of HVAC equipment in early buildings, along with the continuous progress of building technology and control technology, the electrical automation control in intelligent buildings has also developed rapidly [18]-[20]. The automation of the electrical control of intelligent buildings is a necessary factor to improve the living standards of the occupants, and its technology is being applied more and more widely, which has a positive effect on improving the function of intelligent buildings. The automation control of electrics realizes the remote control and management of terminal equipment, which improves the living standard and quality of occupants [21]-[24].

In this paper, before formulating the system control scheme, the system energy consumption prediction model based on BP neural network algorithm is constructed, so that the formulated energy-saving and emission reduction electrical automation system control scheme is more in line with the real-life situation, which is the main innovation point of this research. A building project is selected as the research case of this project, in order to implement the concept of sustainable development and energy saving and emission reduction policy, the energy saving and emission reduction electrical automation system for intelligent buildings is designed. In order to realize intelligent monitoring and prediction of system energy consumption, it is proposed to use BP neural network algorithm to construct a system energy consumption prediction model, which is conducive to the formulation of a more reasonable system control scheme. Under the premise of known system energy consumption, the objective function, constraints and solution algorithm are set, and the task of constructing the system scheduling control model is completed. In the process of empirical analysis, the prediction model and scheduling control model are first explored and analyzed to obtain the optimal energy saving and emission reduction electrical automation system control scheme, for example, the system can automatically respond to the signals transmitted by the indoor sensors to avoid excessive operation of the equipment, so as to reduce the unnecessary loss of power, cost, and carbon emissions. Finally, the practical application effect of the system control scheme is investigated and analyzed to further improve the rigor of the research results.

II. Energy-saving and emission-reducing electrical automation for intelligent building systems

II. A. Overview of construction works

The construction project of a commercial area in the economic and technological development zone of a city is selected as an engineering project of energy saving and emission reduction electrical automation system control technology for intelligent buildings. The total planning area of the project is 58,134 m² and the air-conditioned area is 30,508 m².The carbon emission and energy consumption of the construction project is the focus of the construction. By increasing the degree of electrification and the use of natural gas, the proportion of high-quality energy and clean energy is enhanced. During the implementation of the construction project, the prevention and control of pollutants due to fossil fuels, etc. are strengthened to reduce the intensity of greenhouse gas and air pollutant emissions. The building has four floors above ground, a U-shaped plan, an east-west length of 69.4m, a north-south length of 83.5m, a frame structure, and a total floor area of 13,303.27m². The main functions of each floor are as follows:

Main functions of the first floor: assembly building productive training base, masonry training room, mechanics and steel processing training room, 1+X vocational skills training center, concrete 3D printing R&D center, intelligent building VR training room, preparation room, office, fire watch room, distribution room, bathroom.

Main functions of the second floor: construction organization training center, bidding training center, data room, town planning training center, engineering literacy training center, construction organization sand table, engineering cost machine room, building materials laboratory, preparation room, office, bathroom.

Main functions of the third floor: BIM studio, BIM training machine room, fire simulation training center, engineering costing machine room, training classroom, data room, preparation room, office, bathroom.

Main functions of the fourth floor: construction equipment production training center, urban and rural planning informationization machine room, urban and rural planning professional training center, construction simulation training room machine room, construction CAD machine room, water conservancy engineering training room, training classroom, data room, preparation room, office, bathroom.

There are six safety exits on the first floor of the project, and five evacuation stairwells on each of the second to fourth floors to meet the fire evacuation requirements. The building is four floors above ground, the height of the first floor is 6.0m, the height of the second to fourth floors is 4.5m, and the height difference between indoor and outdoor is 0.45m.The project is planned to be formally completed in 2019, and formally delivered in 2020. Building volume coefficient Building exterior area $F0$=12495.29m². The volume of the building $V0$=63030.95m³, and the coefficient of building shape $S=F0/V0=0.2$.

II. B. Energy saving and emission reduction automation system design

II. B. 1) Functional design of lighting

In the design process of the linkage control technology of the energy reduction automation system, the designers should first improve the existing lighting function, so that it can simultaneously meet the needs of the usual and emergency, and practicing the concept of ecological and environmental protection, so that the planning of the lighting circuit is more energy-saving and reasonable. In the specific design process, the designers should fully understand the relevant provisions of the drawings, and based on the structural characteristics of the building itself, the lighting circuit of each device for a reasonable layout. Usually, housing lighting is powered by 220V, while 380V is used in commercial buildings. Intelligent dimming control system as shown in Figure 1, in order to ensure the safety of the circuit, should be designed with the help of electrical intelligent linkage control technology for emergency systems, that is, in the emergency equipment assembled with a total capacitance of 10kV of independent power supply, so that it can meet the short-term demand for electricity in the building in the case of a wide range of building power supply failure. This intelligent lighting system should be oriented to the actual needs of building users, with the help of intelligent systems to ensure the controllability of the lighting function. In addition, this kind of electrical intelligent system linkage control technology can also automatically adjust the building's power supply voltage, avoiding the phenomenon of unstable voltage leading to the reduction of lighting effect to the maximum extent possible.

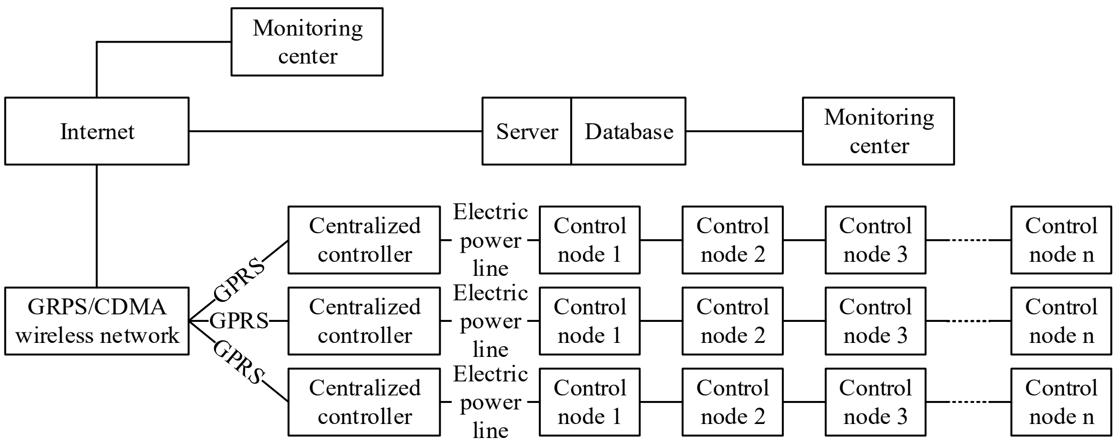


Figure 1: Intelligent dimming control system

II. B. 2) Equipment implementation design

With the further development of intelligent buildings, the overall system of the building has been able to be controlled with the help of independently operating modular mechanisms. Therefore, while using the energy-saving and emission reduction automation system control technology, the rail module should be installed in accordance with the relevant national regulations, so that its diameter is controlled within 3cm, and in the actual installation process, the environment around the module should also be taken into account. This kind of module is characterized by small volume, so it occupies relatively small space. In addition, since the rail itself has a strong resistance to pressure and tension, it can provide effective protection for the box, simplifying the installation procedure and thus providing more disposable space for the occupants.

II. B. 3) System operational design

In the process of optimizing the control technology of the energy-saving and emission reduction automation system, the operation of the system should be reasonably designed in order to further exert the advantages of this new technology. If a certain module in the system stops running, it will lead to the failure of the building electrical intelligent system and even cause serious consequences. In the working process of this intelligent system, the transmission of data and information mainly relies on the joint control technology, and the corresponding module is run separately. Although there are interconnected channels between modules, the degree of connection is not strong, and the modules still rely on independent operation, and their contact with the outside world mainly relies on output ports, USB interfaces and IP interfaces. In order to ensure stable operation of the internal system, attention should be paid to the stability of the interfaces when selecting them.

III. System energy consumption prediction and control

III. A. System energy consumption prediction model

Through the macro-level prediction of energy consumption changes in energy-saving systems for intelligent buildings, after testing and analyzing the actual use of each sub-system, the establishment of a prediction model of energy loads and renewable energy generation of equipment such as electricity, heat and other equipment in buildings and their corresponding system algorithms, the construction of an online optimization and control of the entire system and sub-systems objective function has been investigated, and the efficient prediction and operation of the overall system has been determined. The efficient prediction and operation control strategy of the overall system is determined. There are many methods and theories about the prediction of electricity consumption, water consumption, gas consumption, etc. in construction buildings, such as fuzzy prediction method, random forest generation, neural network method and other control algorithms and strategies. This topic will use the prediction of energy consumption of energy-saving system based on BP neural network algorithm, which is one of the most commonly used model strategies, using BP neural network algorithm can be used to make a reasonable prediction of energy consumption of energy-saving system oriented to intelligent buildings, so as to achieve the purpose of efficient energy saving in the building.

III. A. 1) BP Neural Network Algorithm

The BP neural network is a multi-layered feed-forward neural network generated according to the computational theory of error back-propagation, which consists of an input layer, an output layer, and one or more hidden layers, and each layer consists of multiple neurons that can be computed in parallel, and there is no connection between neurons in the same layer, and neuron nodes between layers are connected to each other in a fully interconnected way [25]. If we want to improve the prediction accuracy, we can increase the number of hidden layers of the BP network to further reduce the training error, so as to achieve the purpose of improving the prediction accuracy. However, this will make the structure of the neural network more complex, so that the training time of the network weights will be extended and the training speed will be slowed down. The BP network with a single hidden layer is sufficient to fit any complex nonlinear function, and has the advantages of simple computation and fast learning speed.

Learning of BP neural network consists of two stages, the first stage is forward propagation through the input signal. The second stage is back propagation through error [26]. In the first stage, the training sample information is first fed at the input layer and then processed by the hidden layer before being passed to the output layer. If there is an error between the actual output and the expected output, it goes to the second stage, which is the error back propagation stage. This process is the error of the output signal from the hidden layer to the input layer in accordance with the original pathway, and then the error signal obtained from each layer were assigned to all neuron units in each layer, and each neuron based on the signal to change the weights of each network connection, and finally make the error signal gradually reduced. These two phases are repeated over and over again. The network learning phase is actually the process of constantly adjusting and modifying the connection weights. The process is ongoing until the error value is reduced to the allowable range or the predefined number of training sessions is reached.The basic steps of the BP algorithm are as follows:

(1) Initialize the weights and thresholds of the network, i.e., set all network connection weights w and thresholds b to a random number within the interval [-1, +1].

(2) Given a set of network training sample set, which contains input vector P with desired output result T.

(3) Calculate the output values of the hidden and output layers based on Eq.

The output of the hidden layer is:

$$al_i = f1(\sum_{j=1}^{r} \omega l_i p_j + bl_i) \tag{1}$$

The output of the output layer is:

$$a2_k = f2(\sum_{i=1}^{s1} \omega 2_{ki} al_i + b2_k) \tag{2}$$

(4) Adjust the connection weights and thresholds of the network.

The standard BP neural network algorithm uses a gradient descent learning algorithm, which adjusts the weights and threshold vectors with the formula:

$$x(k+1) = x(k) + \alpha D(k) \tag{3}$$

In Eq. $x(k+1), x(k)$ denotes the network connection weights and thresholds at the $k+1, k$ nd iteration, respectively, α denotes the training rate, and $D(k)$ is the negative gradient of the network error to the weights and thresholds when the algorithm proceeds to the k th iteration, i.e., the fastest descending direction of the gradient.

(5) Calculate the total error of the neural network. I.e:

$$E = \frac{1}{2}\sum_{k=1}^{s2}(t_k - a2_k)^2 \tag{4}$$

(6) Cycle through steps (2) through (5) until the error accuracy satisfies ε, i.e., $E < \varepsilon$.

III. A. 2) Mathematical modeling

The use of BP neural network way for intelligent building-oriented energy-saving system energy consumption prediction, prediction model need to consider the intelligent building-oriented energy-saving system energy consumption have an impact on a variety of factors variables, and need to consider analyzing the feasibility of applying the way, the system energy consumption prediction model structure as shown in Figure 2. However, the actual impact of public buildings energy consumption of many factors, such as indoor and outdoor climatic conditions, the change of law of people's activities, changes in the opening of the load in the building, etc., these changes will have a significant impact on the system energy consumption. This project to carry out the prediction of the overall energy consumption of the building to take into account the factors affecting it, specially selected climatic conditions, the number of office workers, indoor temperature, time factors and other factors as the input layer, through the weights to adjust the final output of the predicted energy consumption value. The specific steps are as follows:

(1) Extract a certain sample from the training set and input the information into the network.

(2) The real-time output of the neural network can be derived after processing the information data forward layer by layer through each connected node.

(3) Measure the amount of deviation of the actual and desired output information data.

(4) Return the deviation to the previous layers layer by layer, and load all the error data on the connection weights according to certain principles, so that the connection weights of the whole neural network are gradually transformed to the goal of deviation reduction.

(5) Repeat the above process for each input-output sample in the whole training set until the deviation of the whole set of practice samples is reduced to the required level.

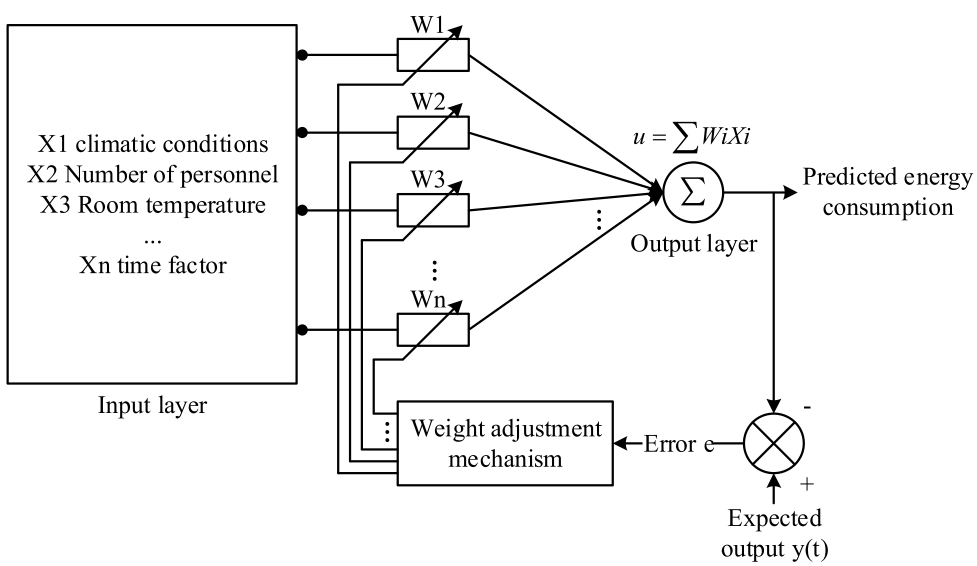


Figure 2: System energy consumption prediction model structure

III. B. System Scheduling Control Model

The above adopts the energy saving and emission reduction electrical automation system energy consumption prediction model based on BP neural network, the use of BP neural network on the overall energy consumption of the system and power generation trend to make a prediction, and analyze the evolution of the system energy consumption process and development trend of the characteristics of the macroscopic, and in this way to guide the system scheduling and control work for the system to provide a scientific decision-making basis for the system energy consumption scheduling and control work. According to the energy saving and emission reduction electrical automation system's goal is to ensure safe operation and use of comfort under the premise of ensuring that the building in different operating modes to make the system run load energy consumption minimum, and maximize the consumption of renewable energy energy consumption. Due to the system's energy consumption system load demand has diverse characteristics, the main energy consumption of the system for dynamic prediction and response to its integrated demand, and then use a reasonable scheduling control model to ensure that the building indoor environmental quality requirements, while achieving the energy saving and emission reduction system control of the target effect. Generally includes the following aspects of work:

(1) Construct the objective function under the key index parameters.

(2) Setting the constraints on the safety of equipment operation and the high quality of the building environment.

(3) Simulate and solve the corresponding objective function in the system to filter out the optimal control scheduling program and execute it. The details are as follows:

III. B. 1) Objective function

Energy saving and emission reduction of electrical automation system control is the main purpose is to ensure that the system operation safety, maximize the consumption of renewable energy photovoltaic power, at the same time make the system operation and management costs are minimized, the scheduling model of the objective function is as follows:

$$MinJ = \sum_{t=1}^{n}(C_{grid}P_{grid} - C_{pv}P_{pv} - C_{AC}P_{AC})\Delta t \tag{5}$$

where J is the total operating cost of the building, C_{grid} is the unit off-grid tariff for time period t, yuan/Kwh. P_{grie} is the power input to the building mainline from the grid for time period t, kw. C_{pv} is the unit on-grid tariff for time period t, yuan Kwh. P_{pv} is the power output to the grid from the building mainline for time period t, kw. C_{AC} is the compensation tariff for the battery in time period t, yuan/Kwh. P_{AC} is the power output/input from the battery to the building mains in time period t, kw.

Combined with the current development trend of intelligent buildings, set the minimum power consumption and carbon emission target function of energy saving and emission reduction electrical automation system. It is shown as follows:

$$\min W = a_i P_i^2 + b_i P_i + c_i \tag{6}$$

$$\min E_{CO2} = a_{is} P_i^2 + b_{is} P_i + g_{ic} \tag{7}$$

In the formula, $\min W$ indicates the minimum power consumption, a_i, b_i, c_i are the system energy consumption characteristic coefficients, P_i is the energy saving and emission reduction electrical automation system generated in the operation process of the active power, $\min E_{CO2}$ is the minimization of the emission target, a_{is}, b_{is}, c_{is} are the system emission characteristic coefficients, and g_{ic} is the CO_2 emission characteristic coefficients of the system.

III. B. 2) Constraints

The system scheduling operation constraints specifically include grid constraints, battery constraints, the daily energy management of this system mainly includes power energy consumption for real-time scheduling.

(1) Power balance constraints

According to the automation control technology of power generation and power consumption unit, the system can realize the power balance of power generation, power consumption and power exchange with the grid within the system. The key to realizing the power balance of the three is to adjust the power generation according to the power consumption and the power exchanged with the power grid, in which the power exchanged with the power grid is decided by the higher-level grid scheduling organization and the power is relatively stable, so the power consumption power becomes a key factor affecting the power adjustment of the power generation. To address this issue, the smart microgrid fully considers the AC load and DC load characteristics with high probability of use in the building, and its power supply demand and impact on the smart microgrid, and establishes a mathematical model of the microgrid load based on the dynamic characteristics of the load in the near-zero-energy office building, and through the prediction of power generation dynamics of the microgrid, the PV power generation system subsystem always adopts the maximum power tracking mode to generate as much as possible The PV power generation system subsystem always adopts the maximum power tracking mode to generate as much PV power as possible to supply the main line of the circuit for system use. The predicted data can be used to regulate the total power generation, power consumption, and power exchanged with the grid, and the three power balances are realized. i.e:

$$P_{grid}^{t} + P_{pv}^{t} = P_{total}^{t} + P_{AC}^{t} \tag{8}$$

where P_{grid} is the power exchanged with the grid, kw, P_{pv} is the photovoltaic power, kw, P_{AC} is the battery charging power, and P_{total} is the total power of all operating equipment and appliances in the building system, kw.

(2) Battery constraints

Based on the power supply and load peak and valley difference is very large problem, the means of battery device and demand mutual response is mainly manifested as peak shaving and valley filling, according to the level of market price of electricity to autonomously optimize the power supply behavior, that is, charging in the grid load trough period of low price of electricity, in the peak period of the grid load of high price of electricity when discharging. The battery operation constraints are:

$$\begin{cases} SOC_{low} \le SOC_{t} \le SOC_{high} \\ 0 \le P^{t} \le P_{filling\ \max} \\ 0 \le P^{t} \le P_{put\ \max} \end{cases} \tag{9}$$

In the formula, $P_{filling\ \max}$ and $P_{put\ \max}$ for the battery maximum charging power and maximum discharge point power kw, SOC_{low}, SOC_{high} for the battery under normal circumstances of the lowest discharge limit and maximum capacity charging upper limit, take the value of 20% and 90%, respectively.

III. B. 3) Optimal control scheduling scheme based on genetic algorithm

After determining the objective function and constraints of the energy-saving and emission reduction electrical automation system, it is necessary to use certain algorithms for optimization calculation. Considering the online real-time control of the energy saving problem, the optimization search time for completing the above algorithm is long, so the genetic algorithm is used as the real-time optimization algorithm. Genetic algorithm can be regarded as an optimization method, which gives an evolutionary function by encoding the problem similar to a chromosome, and the most suitable chromosome, which corresponds to the optimal solution of the problem, is retained by certain genetic operations such as selection, crossover and mutation [27]. Genetic algorithms deal with optimization problems by encoding all the independent variables, commonly used binary codes representing a solution determined by the values of one independent variable, the objective function of the optimization problem as the environment in which the population is located, and the value of the objective function as the individual's fitness to the environment. Genetic algorithm will be a complex nonlinear problem after effective search and dynamic evolution to achieve the characteristics of the optimization state, with and other algorithms have different characteristics. Genetic algorithm adopts the group way to organize the search, can search multiple regions in the solution space at the same time, is a kind of heuristic search, its search time consumption and efficiency is better than other optimization methods, the problem function is very little restriction, that is, it can be a mathematical function and other explicit functions, but also mapping matrices, neural networks and other implicit functions. Genetic algorithm is an iterative process, in each iteration to retain a set of candidate solutions, according to the advantages and disadvantages of their solutions are sorted, and according to some indicators from which some solutions are selected, the use of genetic operators to operate on them, to produce a new generation of a new set of candidate solutions, until a certain convergence conditions are met. The main processes are as follows:

(1) Determine the coding method

Determine the coding mode, that is, to convert the feasible solution of a problem from its solution space to the search space that the genetic algorithm can deal with, the main coding mode is to use binary coding to realize the parameterization of the model, according to a certain order of every few binary digits correspond to a parameter variable, each bit of the binary that is a gene on the chromosome, the binary string that is, the chromosome, the chromosome length depends on the range of the parameter values and the The length of the chromosome depends on the range of parameter values and the model resolution, and the relationship is as follows:

$$2^{l} = \frac{\max(m) - \min(m)}{\Delta m} + 1 \tag{10}$$

In Eq. (10), $\max(m)$ and $\min(m)$ are the upper and lower limits of the values of the problem domain parameters, respectively, Δm is the model parameter resolution, and 1 is the chromosome length.

(2) Determine the fitness function

The fitness function is a measurement function of the problem solving results, which is an indicator of the chromosome's adaptation to the environment and an objective function reflecting the actual problem. Suppose there is a problem to be optimized:

$$\begin{gathered} Y = f(x_1, x_2, \cdots, x_n) \\ Y \in R \\ (x_1, x_2, \cdots, x_n) \in \Omega \end{gathered} \tag{11}$$

where $x_1, x_2, \cdots, x_n$ is the independent variable, $x_1, x_2, \cdots, x_n$ of each set of values $(a_1, a_2, \cdots, a_n) \in \Omega$ constitute a solution to the problem, Ω is the solution space of the problem, F is a real number of the real number domain R, the goal of optimization is to find a set of values $(\alpha_1, \alpha_2, \cdots, \alpha_n) \in \Omega$ of $x_1, x_2, \cdots, x_n$, making $y = F(\alpha_1, \alpha_2, \cdots, \alpha_n)$ the largest, the fitness function and the objective function of the actual problem is consistent with the objective function, for the minimization of the objective function of the problem, the fitness function can be taken as the inverse of the objective function.

(3) Determination of selection strategy, the larger the fitness value the greater the probability of being selected, the commonly used selection method is the fitness ratio method, also known as roulette selection, that is, each chromosome produces a number of offspring is proportional to the size of its fitness value and the total number of chromosomes remains unchanged.

Assuming that the size of the population is n and the fitness value of individual A_i is $f(A_i)$, the probability $P(A_i)$ that individual A_i will be selected is:

$$P(A_i) = \frac{f(A_i)}{\sum_{i=1}^{n} A_i} \tag{12}$$

(4) Genetic algorithm itself control parameter selection, the main parameters to be selected are the string length of the coding string 1, the population size n, the crossover probability p_c and the mutation probability p_m.

(5) The design of genetic operators, the genetic operators of simple genetic algorithm only include selection, crossover and mutation, and the advanced genetic algorithm contains some complex genetic operators, such as inverse operators.

Crossover operation is the characteristic of genetic algorithm that distinguishes it from other evolutionary operations, and it is the main method to produce new individuals, including: single-point crossover, two-point crossover, uniform crossover and arithmetic crossover.

(6) Determine the termination conditions of the algorithm, which are the following or a combination thereof: specify the number of evolutionary generations, i.e., the maximum number of iterations. The fitness value of a solution in the population reaches a certain pre-specified range. For a number of consecutive generations, the individuals in the population no longer change.

From the characteristics and design process of the genetic algorithm, it can be seen that the genetic algorithm is suitable to be used as an optimization solution algorithm for the scheduling control model of the energy-saving and emission-reducing automated system, which can shorten the time of optimization searching, so as to get the optimal energy-saving and emission-reducing automated system scheduling and control scheme.

IV. Empirical analysis of system energy consumption prediction and control

IV. A. Empirical analysis of system energy consumption prediction

IV. A. 1) Indicators for the assessment of forecasting models

In this paper, three indicators are used to judge the performance of the prediction model, which are the root mean square error (RMSE), the mean absolute percentage of error (MAPE), and the coefficient of determination R^2, which is calculated by the following formula:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{y}_i - y_i\right)^2} \tag{13}$$

$$MAEP = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|\hat{y}_i - y_i\right|}{y_i}\times 100\% \tag{14}$$

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(\hat{y}_i - y_i\right)\left(\hat{y}_i - y_i\right)\right]^2}{\sum_{i=1}^{n}\left(\hat{y}_i - y_i\right)\sum_{i=1}^{n}\left(\hat{y}_i - y_i\right)} \tag{15}$$

where $\hat{y}_i$ is the predicted value and y_i is the actual value.

IV. A. 2) Parameter setting

In this paper, four prediction models are established as CNN (Conventional Convolutional Neural Network), RNN (Conventional Recurrent Neural Network), DNN (Deep Neural Network) and BP Neural Network. These three prediction models (CNN, RNN, DNN) are used as a performance comparison of the proposed models in this paper. All the codes related to the experiments in the paper were implemented in Python software using the machine learning library Scikit-Learn (version 0.21.1). This experiment uses ten-fold cross-validation to validate the model. Cross-validation is a method for evaluating predictive models by repeatedly dividing the training set into a training set and a validation set. After ten-fold cross-validation, the hyperparameters optimized by the model and their specific values are the number of base learners (120, 120, 100), the minimum number of samples required to split the internal nodes (16, 16, 4), and the minimum number of samples required for leaf nodes (8, 8, 2). The number of hidden layers of the model is 3, the number of neurons in the hidden layer (100, 200, 100), and the learning rate is 0.001.

IV. A. 3) Analysis of forecast results

The data are obtained from an intelligent building network and divided into training and test sets according to a certain ratio, Figure 3 shows the comparison curve between the predicted value and the true value of the energy consumption of the energy saving and emission reduction automation system of the different models under the 72-hour test set, and Table 1 shows the comparison of the prediction errors of the different models for the training set and the test set, in which the bolded values indicate that the model has the best prediction performance for this test set under this performance evaluation . From this table, it can be seen that the prediction performance of CNN compared with RNN and DNN models on the test set, the former's RMSE and MAPE are reduced by 2.424, 1.895 and 1.281% and 1.09%, respectively, which shows that the performance of the system prediction model based on the Convolutional Neural Networks is better than that of the RNN and DNN models, which suggests that the CNN can extract the effective practical impacts on the energy-saving The system energy consumption prediction model of BP neural network reduces RMSE by 0.928, 3.352, 2.823, MAPE by 0.491%, 1.772%, 1.581%, and R2 reaches 0.847, which is the highest among the four models, comparing with other models, indicating that the predicted value has a good relation with the actual energy consumption. It shows that the predicted value has a good fit goodness of fit with the actual energy consumption. It can be shown that the BP neural network algorithm can filter out some of the influencing factors of energy consumption in energy-saving and emission reduction automation system, which improves the model prediction accuracy while reducing the model complexity.

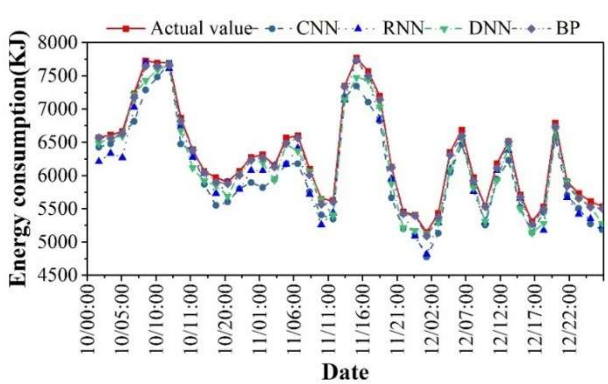


Figure 3: A graph comparing the predicted value to the true value

Table 1: Comparison of prediction performance of different models

Model	Data set	RMSE	MAPE/%	R^2
BP	Data set	**4.126**	**2.346**	**0.847**
	Training set	4.277	2.512	0.814
CNN	Data set	5.054	2.837	0.807
	Training set	4.712	2.657	0.779
RNN	Data set	7.478	4.118	0.658
	Training set	7.084	3.857	0.816
DNN	Data set	6.949	3.927	0.447
	Training set	12.547	7.946	0.806

Fig. 4 shows the scatter plot of the predicted and true values of the system energy consumption under the four models in the test set, where (a) to (d) are BP, CNN, RNN, and DNN, respectively. It is obvious from the figure that under the model of this paper, the scatter points are distributed near a straight line with a slope close to 1. The correlation coefficient r between the true and predicted values also reaches 0.913. It shows that the model in this paper predicts the energy consumption of the energy efficient electrical automation system better without overfitting. In addition, it can be seen that the energy consumption is mainly distributed between 4000KJ and 7700KJ.

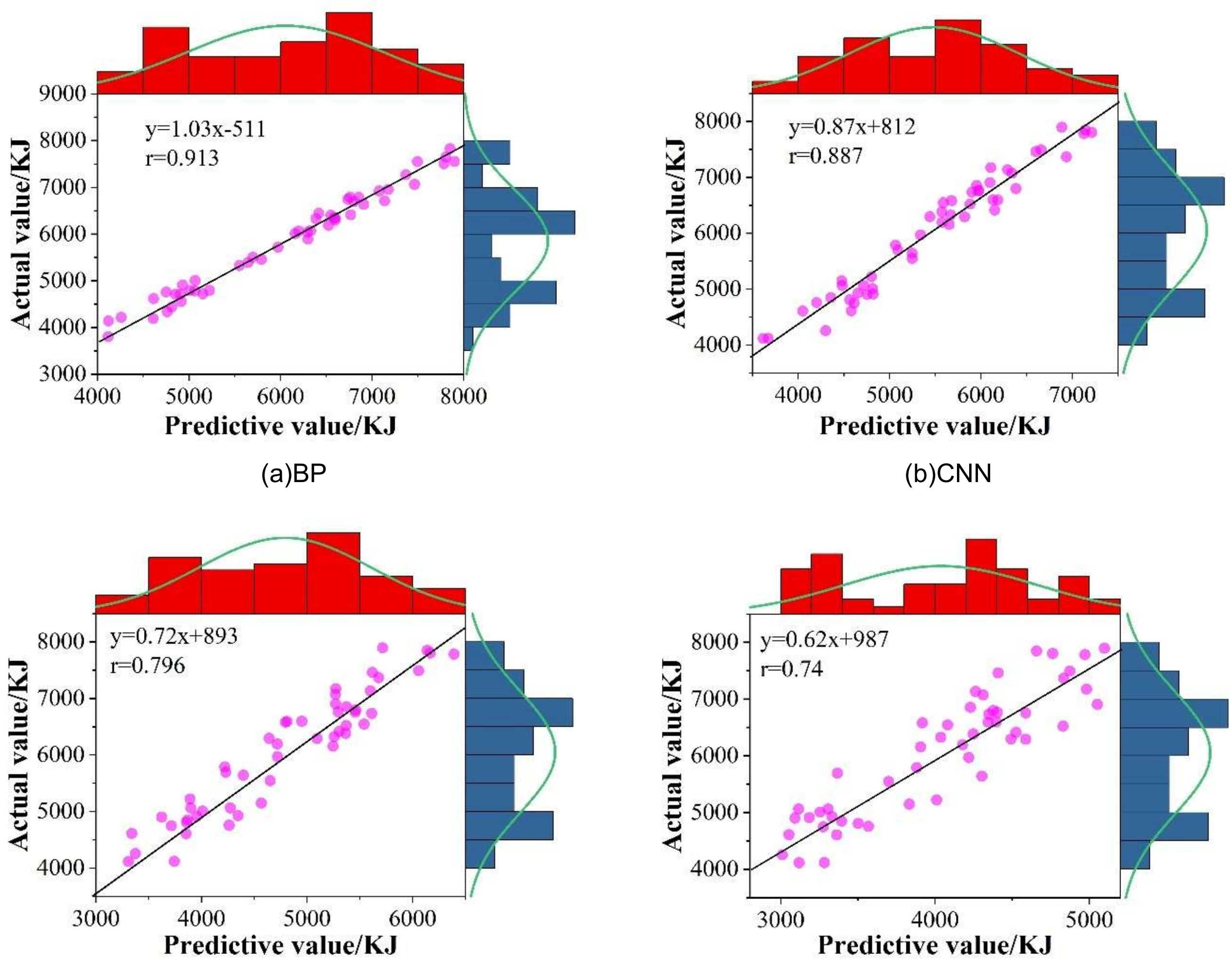


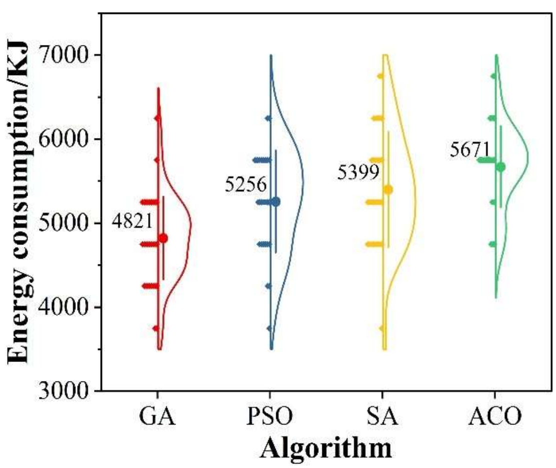
Figure 4: Scatter plot of predicted and true values

IV. B. Empirical analysis of system dispatch control

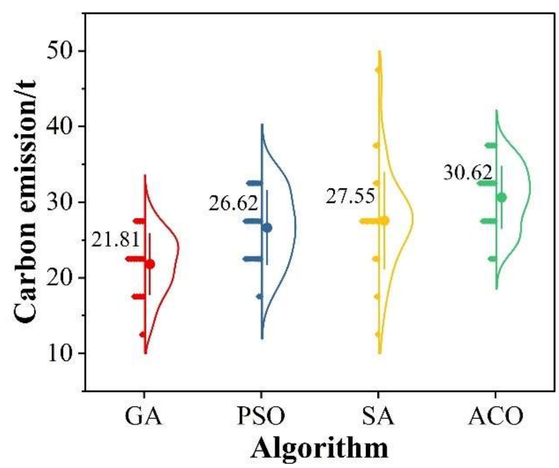
By analyzing the energy consumption prediction of the energy saving and emission reduction automation system above, the energy consumption distribution range of the system in three days' time is derived, which provides data support for the empirical analysis of the system scheduling control. Next, with the help of the genetic algorithm and constraints mentioned above, the objective function set is solved, and then the optimal scheduling control scheme of the energy emission reduction automation system is derived, and the actual operation effect of the scheduling control scheme is explored, which is analyzed as follows:

IV. B. 1) Analysis of the objective function solution

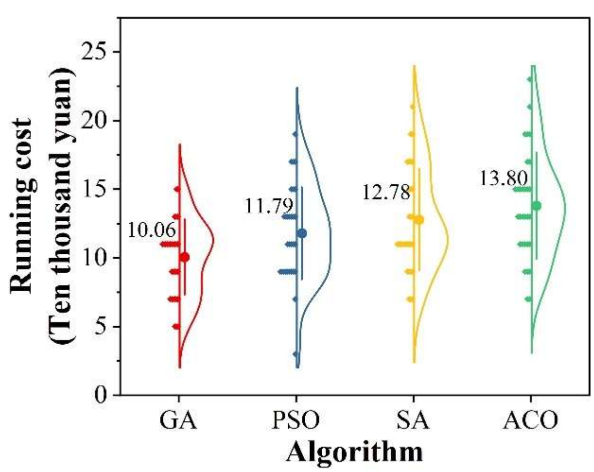
In order to reflect the priority of genetic algorithm in the control of energy saving and emission reduction electrical automation system, three comparison algorithms (PSO: particle swarm algorithm, SA: simulated annealing algorithm, and ACO: ant colony algorithm) are set, and the relevant parameters of the algorithms are set. Combined with the above constraints and the results of the system energy consumption distribution, the set objective function is solved, and the comparative analysis of the objective function solving results is shown in Fig. 5, in which (a) ~ (c) represent the optimal solution of energy consumption, the optimal solution of CO_2 emission, and the optimal solution of operation cost, respectively. Based on the performance of the data in the figure, the genetic algorithm to solve the objective function results were 4821KJ, 21.81t, 100,600 yuan, compared with the other three algorithms perform better, indicating that the genetic algorithm can realize the global optimal energy saving and emission reduction electrical automation system control, not only reduces the energy consumption and CO_2 emissions, at the same time, makes the system operation and management costs at a minimum. According to the results of the objective function solution, the optimal energy-saving and emission reduction electrical automation system control program is formulated (e.g., the system can automatically respond to the signals transmitted by the indoor temperature and humidity sensors and adjust the size of the temperature and humidity signals to avoid excessive operation of the air conditioner and other equipment, and to reduce the unnecessary loss of electrical energy, costs, and carbon emissions).



(a) Optimal energy consumption solution



(b)Optimal solution of CO_2 emission



(c) Run A optimally

Figure 5: Comparison of objective function solution results

IV. B. 2) Analysis of practical application effects

In recent years, the problem of energy crisis is becoming more and more serious. Buildings as a large energy consumer, energy consumption accounts for about 24.9% of the total energy consumption in the country, indoor heating as the most important heating method in cold regions and cities in cold regions. For this reason, this subsection explores the effectiveness of the system control scheme in indoor heating in terms of temperature, CO_2, and energy consumption. Figure 6 shows the outdoor temperature change curve from 08:00 to 21:00 on December 10, 2022, and Figure 7 shows the indoor temperature and CO_2 volume data collected by the energy-saving and emission reduction electrical automation system on December 10th. In order to avoid energy saving and emission reduction electrical automation system regulating valves, inverters and other actuators frequent action, energy saving and emission reduction during the system for the optimization of scheduling and control, the system control and regulation cycle of 60min, the system data acquisition cycle of 10min, the actual operating data through the energy saving and emission reduction system collected and stored in the data server, energy saving and emission reduction electrical automation system control program put into operation since the control links are running well, the average indoor temperature and CO_2 volume data collected. links run well, the average indoor temperature is maintained at about 12~19℃, while the outdoor temperature fluctuates within the range of 4~10℃ (due to the indoor temperature gap caused by the indoor in the heating), and the volume fraction of carbon emissions generated by the system is controlled at 530~610×10^{-6}, which indicates that under the action of the system control program, the various values are all in a reasonable range, which verifies that the system control program has a good The system control scheme has a good practical operation effect.

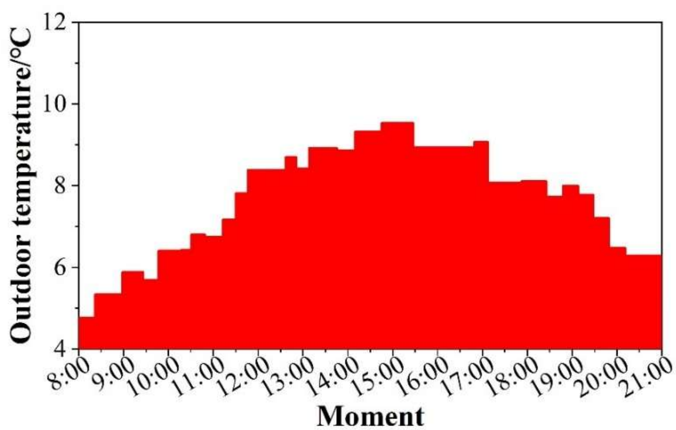


Figure 6: Variation trend of outdoor temperature on December 10

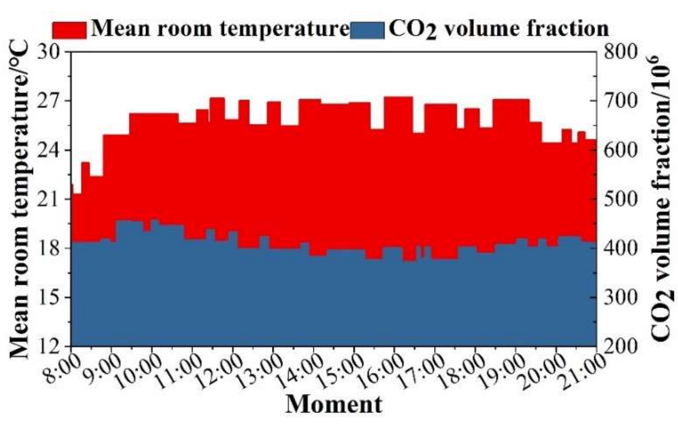


Figure 7: Change curve of indoor temperature and CO2 volume fraction

Fig. 8 shows the comparison of power consumption between the heating seasons of 2022-2023 and 2023-2024, where the 67th to 85th d of 2022-2023 and the 53rd to 68th d of 2023-2024 belong to the period of the cold winter season, which has a lower level of energy consumption. Compared with the heating season of 2022-2023 (106,042.9 kW·h) before the operation of the system control scheme, the heating season of 2023-2024 (77,332.4 kW·h) saves 27.07% of electricity under the condition that the average outdoor air temperature is basically the same.

According to the electricity (equivalent) standard coal conversion factor 0.4040kg/(kW·h), 1kg standard coal emission 2.622kg carbon dioxide calculation, the annual savings of standard coal 11.6t, reduce carbon dioxide emissions 30.415t, further illustrates that energy saving and emission reduction electrical automation system control program in the actual operation of the process of excellent application results.

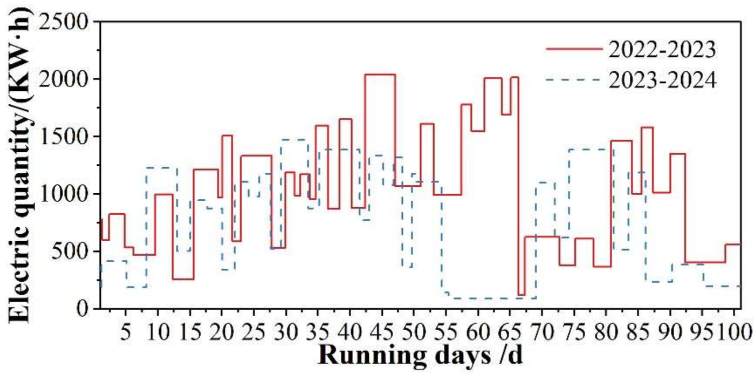


Figure 8: Comparison of electricity consumption in heating season

V. Conclusion

In this paper, from the actual construction project overview, with the help of the corresponding equipment and software, the energy saving and emission reduction electrical automation system is constructed. Between the development of the system control program, it is necessary to use BP neural network to predict and analyze the system energy consumption, revealing the distribution range of system energy consumption. After the energy consumption of the system is known, the objective function and constraints of the system scheduling control model are set, and the genetic algorithm is proposed to be used to simulate the objective function for solving and analyzing, so as to formulate the globally optimal system control scheme, and finally, the analysis of the practical application effect of the scheme is also added. Compared to the heating season of 2022-2023 (power consumption: 106,042.9 kW·h) before the program was operated, the program was formally put into operation in 2023-2024, and it was found that in 2023-2024 (power consumption: 77,332.4 kW·h), saving electricity 28710.5 kW·h, combined with the standard coal conversion factor, converted to carbon dioxide emissions, then 30.415t, verifying the practical application of the energy saving and emission reduction electrical automation system control program developed in this paper.

References

[1] Ghaffarianhoseini, A., Berardi, U., AlWaer, H., Chang, S., Halawa, E., Ghaffarianhoseini, A., & Clements-Croome, D. (2016). What is an intelligent building? Analysis of recent interpretations from an international perspective. Architectural Science Review, 59(5), 338-357.
[2] Mofidi, F., & Akbari, H. (2020). Intelligent buildings: An overview. Energy and Buildings, 223, 110192.
[3] Khan, S. U., Khan, N., Ullah, F. U. M., Kim, M. J., Lee, M. Y., & Baik, S. W. (2023). Towards intelligent building energy management: AI-based framework for power consumption and generation forecasting. Energy and buildings, 279, 112705.
[4] Merabet, G. H., Essaaidi, M., Haddou, M. B., Qolomany, B., Qadir, J., Anan, M., ... & Benhaddou, D. (2021). Intelligent building control systems for thermal comfort and energy-efficiency: A systematic review of artificial intelligence-assisted techniques. Renewable and Sustainable Energy Reviews, 144, 110969.
[5] Panchalingam, R., & Chan, K. C. (2021). A state-of-the-art review on artificial intelligence for Smart Buildings. Intelligent Buildings International, 13(4), 203-226.
[6] Farzaneh, H., Malehmirchegini, L., Bejan, A., Afolabi, T., Mulumba, A., & Daka, P. P. (2021). Artificial intelligence evolution in smart buildings for energy efficiency. Applied Sciences, 11(2), 763.
[7] Wahid, F., Ismail, L. H. B., Ghazali, R., & Aamir, M. (2019). An Efficient Artificial Intelligence Hybrid Approach for Energy Management in Intelligent Buildings. KSII Trans. Internet Inf. Syst., 13(12), 5904-5927.
[8] Fisk, D. (2012). Cyber security, building automation, and the intelligent building. Intelligent Buildings International, 4(3), 169-181.
[9] Farrokhifar, M., Momayyezi, F., Sadoogi, N., & Safari, A. (2018). Real-time based approach for intelligent building energy management using dynamic price policies. Sustainable cities and society, 37, 85-92.
[10] Yoon, S. (2022). Virtual sensing in intelligent buildings and digitalization. Automation in Construction, 143, 104578.
[11] Chen, Z., Xie, M., & Zu, Q. (2023). Electrical Automation Intelligent Control System Based on Internet of Things Technology. Electrica, 23(2).
[12] Jia, R., Jin, B., Jin, M., Zhou, Y., Konstantakopoulos, I. C., Zou, H., ... & Spanos, C. J. (2018). Design automation for smart building systems. Proceedings of the IEEE, 106(9), 1680-1699.
[13] van Roosmale, S., Hellinckx, P., Meysman, J., Verbeke, S., & Audenaert, A. (2024). Building automation and control systems for office buildings: Technical insights for effective facility management-a literature review. Journal of Building Engineering, 110943.
[14] Sami, F. (2022). Optimize electric automation control using artificial intelligence (AI). Optik, 271, 170085.

[15] Ruggiero, S., De Masi, R. F., Assimakopoulos, M. N., & Vanoli, G. P. (2022). Energy saving through building automation systems: Experimental and numerical study of a smart glass with liquid crystal and its control logics in summertime. Energy and Buildings, 273, 112403.

[16] Parekh, R. (2024). Automating the design process for smart building technologies. World Journal of Advanced Research and Reviews, 23(2).

[17] Ma, R., Kareem, S. W., Kalra, A., Doewes, R. I., Kumar, P., & Miah, S. (2022). Optimization of electric automation control model based on artificial intelligence algorithm. Wireless Communications and Mobile Computing, 2022(1), 7762493.

[18] Masroor, M., Rezazadeh, J., Ayoade, J., & Aliehyaei, M. (2023). A survey of intelligent building automation with machine learning and IoT. Advances in Building Energy Research, 17(3), 345-378.

[19] Vandenbogaerde, L., Verbeke, S., & Audenaert, A. (2023). Optimizing building energy consumption in office buildings: A review of building automation and control systems and factors influencing energy savings. Journal of Building Engineering, 76, 107233.

[20] Constantinou, S., Konstantinidis, A., Chrysanthis, P. K., & Zeinalipour-Yazti, D. (2022). Green planning of IoT home automation workflows in smart buildings. ACM Transactions on Internet of Things, 3(4), 1-30.

[21] Van Thillo, L., Verbeke, S., & Audenaert, A. (2022). The potential of building automation and control systems to lower the energy demand in residential buildings: A review of their performance and influencing parameters. Renewable and Sustainable Energy Reviews, 158, 112099.

[22] King, J., & Perry, C. (2017). Smart buildings: Using smart technology to save energy in existing buildings (pp. 1-46). Washington, DC, USA: Amercian Council for an Energy-Efficient Economy.

[23] Metallidou, C. K., Psannis, K. E., & Egyptiadou, E. A. (2020). Energy efficiency in smart buildings: IoT approaches. IEEE access, 8, 63679-63699.

[24] Qiang, G., Tang, S., Hao, J., Di Sarno, L., Wu, G., & Ren, S. (2023). Building automation systems for energy and comfort management in green buildings: A critical review and future directions. Renewable and Sustainable Energy Reviews, 179, 113301.

[25] Hao Zhang,Xulong Cai,Peng Ni,Bowen Qin,Yuquan Ni,Zhiqiang Huang & Fubin Xin. (2025). Prediction of coalbed methane content based on composite logging parameters and PCA-BP neural network. Journal of Applied Geophysics,236,105681-105681.

[26] Cunwu Wang,Xiaobo Peng,Gang Han,Yan Zhao,Yihao Zhu & Ming Zhao. (2025). Research on Coal Structure Prediction Method Based on Genetic Algorithm–BP Neural Network. Applied Sciences,15(5),2514-2514.

[27] Oussama Hasidi,El Hassan Abdelwahed,Moulay Abdellah El Alaoui Chrifi,Rachida Chahid,Aimad Qazdar,Sara Qassimi... & Ahmed Bendaouia. (2024). Data-driven system for intelligent monitoring and optimization of froth flotation circuits using Artificial Neural Networks and Genetic Algorithms. Journal of Process Control,137,103198-.