Journal of Electronic Research and Application, 2024, Volume 8, Issue 3
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Temperature-Based Fan Speed Optimization Strategy

Chucheng Wang, Chongyi Luo*, Junnian Wei, Haiyang Peng, Xiaorong Zhong, Cai Ye

Guangxi Power Grid Co., Ltd., Beihai Power Supply Bureau, Beihai 536006, Guangxi Zhuang Autonomous Region, China

***Corresponding author:** Chongyi Luo, 469085806@qq.com

Abstract: As energy efficiency and indoor comfort increasingly become key standards in modern residential and office environments, research on intelligent fan speed control systems has become particularly important. This study aims to develop a temperature-feedback-based fan speed optimization strategy to achieve higher energy efficiency and user comfort. Firstly, by analyzing existing fan speed control technologies, their main limitations are identified, such as the inability to achieve smooth speed transitions. To address this issue, a BP-PID speed control algorithm is designed, which dynamically adjusts fan speed based on indoor temperature changes. Experimental validation demonstrates that the designed system can achieve smooth speed transitions compared to traditional fan systems while maintaining stable indoor temperatures. Furthermore, the real-time responsiveness of the system is crucial for enhancing user comfort. Our research not only demonstrates the feasibility of temperature-based fan speed optimization strategies in both theory and practice but also provides valuable insights for energy management in future smart home environments. Ultimately, this research outcome will facilitate the development of smart home systems and have a positive impact on environmental sustainability.

Keywords: Smart temperature control; Fan speed optimization; Temperature feedback control; Dynamic speed adjustment; Smart home systems; Energy-saving technology

Online publication: June 14, 2024

1. Introduction

In modern households and office environments, fans serve as common air regulation devices, with their efficiency and adaptability significantly impacting energy consumption and indoor comfort. Traditional methods of fan speed control typically involve manual adjustment or reliance on simple timing mechanisms, lacking flexibility and environmental adaptability. This leads to two primary issues: inefficiency and the inability to precisely respond to indoor temperature changes.

In recent years, experts and scholars have conducted some research on smart fans. For example, Shen *et al.* [1] designed an intelligent electric fan based on fuzzy control; Geng *et al.* [2] developed a smart speed controller for server fans based on fitting functions; Deng [3] designed a smart fan control system, among others documented in other works [4-10].

Research on smart fans holds significant importance in the realms of smart homes and energy conservation. Firstly, from the perspective of environmental sustainability, optimizing fan speeds not only reduces energy consumption but also helps mitigate carbon emissions. Against the backdrop of global efforts to reduce energy consumption and address climate change, any innovation that enhances the energy efficiency of household and commercial devices holds significant value. Secondly, from the viewpoint of technological innovation, applying smart temperature control technology to fan speed regulation not only drives the development of smart home appliances but also opens up new possibilities for the overall integration of smart home systems. The advancement of this technology is expected to catalyze innovation in related fields such as the Internet of Things (IoT), artificial intelligence, and automation control. Furthermore, from the perspective of user experience, precise control of fan speeds to adapt to indoor temperature changes significantly enhances the comfort of living and working environments. This has a direct and significant impact on improving people's quality of life, particularly in extreme climate conditions.

2. Overall system design

The design of this study is based on temperature-based fan speed optimization, with an Internet of Things (IoT) system as the control core. Temperature is collected by temperature sensors, and based on pre-set speed levels, a BP-PID [11] control system is employed to automatically adjust the fan speed. The advantage of the BP neural network [12] lies in its ability to adjust the parameters of the PID controller in real-time based on speed feedback, ensuring smooth transitions in fan speed and avoiding motor damage due to sudden speed changes. The hardware architecture of the designed fan speed optimization strategy is illustrated in **Figure 1**.

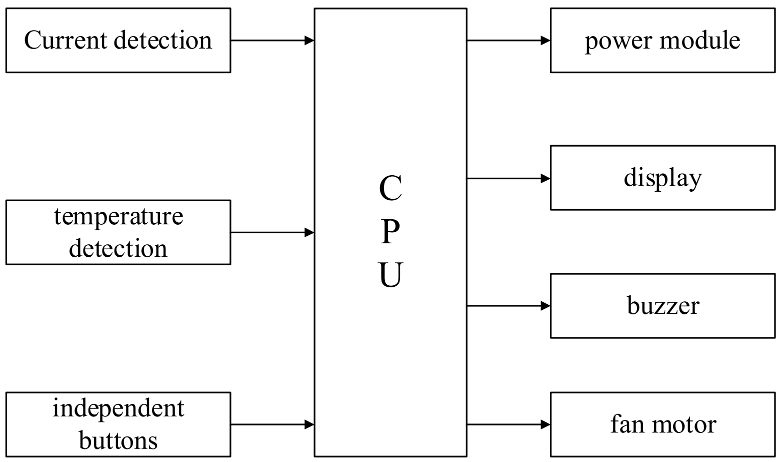

Figure 1. Hardware architecture of fan speed optimization strategy

The processor serves as the core of the intelligent fan, reading and processing data from various modules, and controlling the motor speed, etc. The temperature detection module detects the real-time temperature of the surrounding environment and transmits the environmental temperature information to the processor. Independent buttons are used to control the fan's start and stop functions. The power module consists of a voltage conversion circuit and other related circuits, providing power to the fan motor and control system. The display module is used to show current temperature, fan speed, and other information. The buzzer is used for fan startup alerts. To achieve temperature-based fan speed control switching, a table illustrating the relationship between temperature and speed is designed as shown in **Table 1**.

Table 1. Temperature vs. fan speed correspondence

Environment temperature	Speed level	Speed (rpm)
25–27°C	1	950
27–29°C	2	1000
30–34°C	3	1150
34–38°C	4	1250
> 38°C	5	1350

3. System hardware design

3.1. Power circuit design

The power circuit design is shown in **Figures 2–4**.

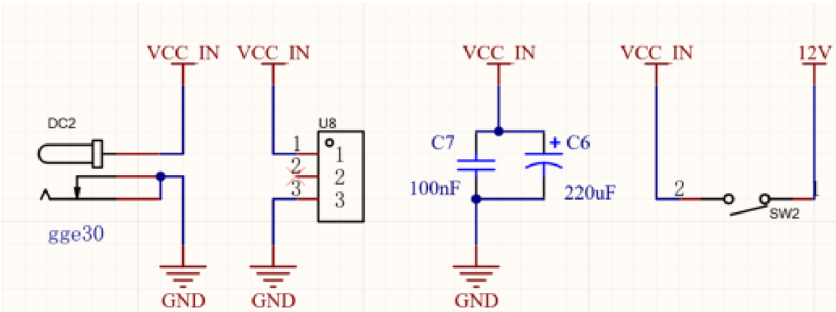

Figure 2. External power input 12V circuit

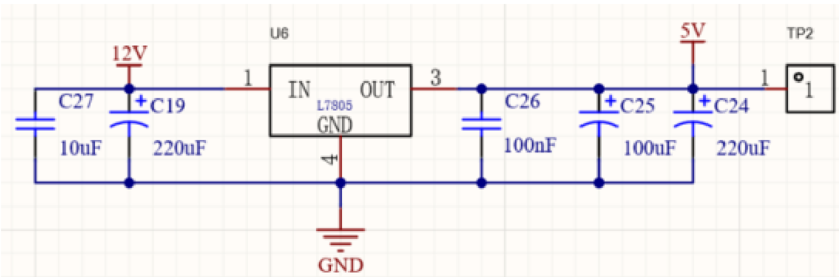

Figure 3. 12V to 5V voltage conversion

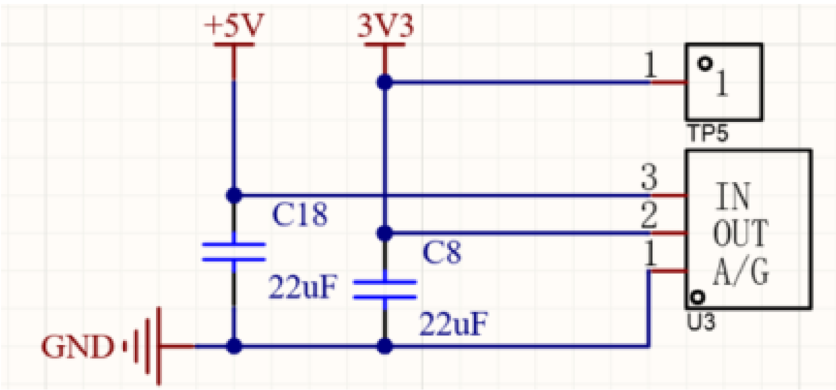

Figure 4. 5V to 3.3V voltage conversion

3.2. Feedback circuit design

The power circuit design is shown in **Figure 5**.

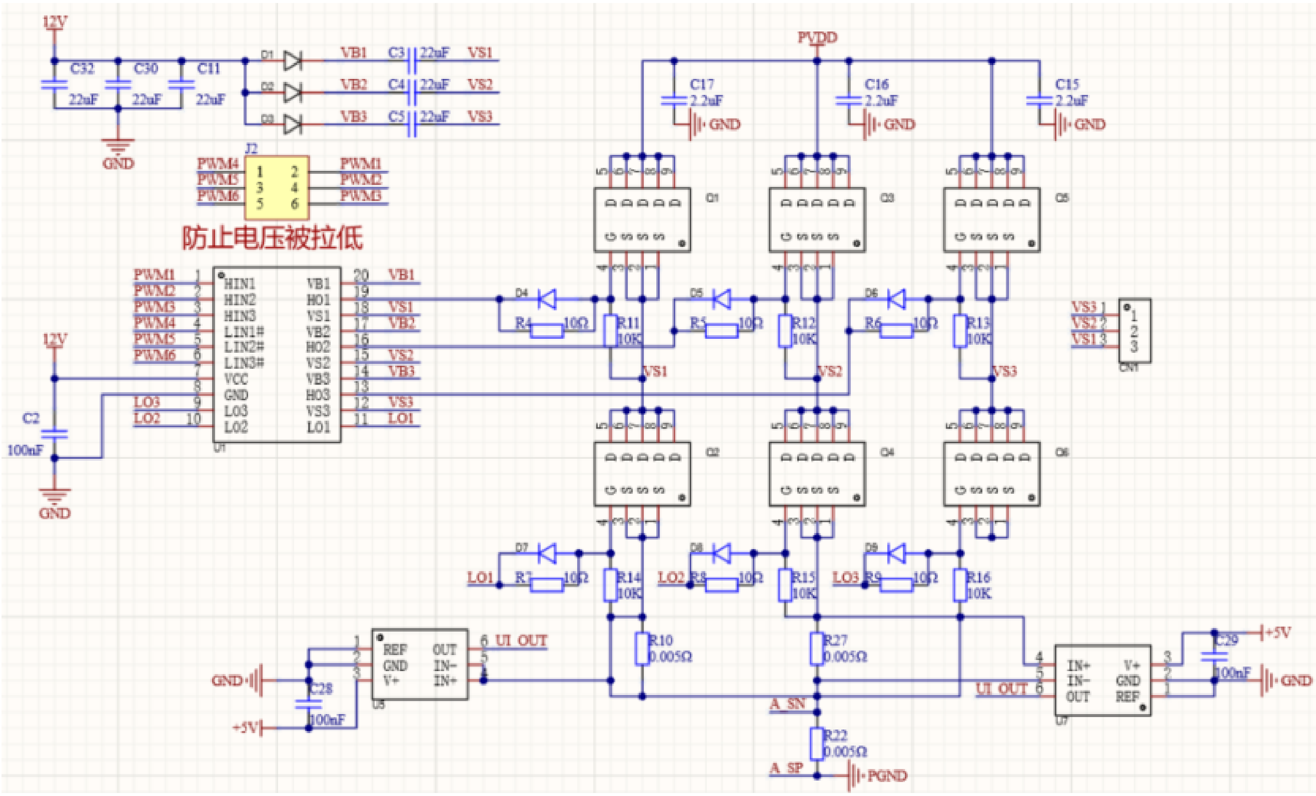

Figure 5. Feedback circuit

4. Design and simulation of temperature-based fan speed controller

Based on the previously designed intelligent temperature-controlled fan speed control system, and addressing the issue of switching fan speed based on environmental temperature, a fan motor speed controller based on BP-PID is designed. The parameters of the PID controller are adjusted by the BP neural network to achieve parameter adaptation, thereby coping with the instantaneous change in fan speed when the temperature changes.

4.1. BP neural network

Traditional PID motor control is susceptible to disturbances both within and outside the system, making it difficult to achieve fast and stable speed control. This paper focuses on temperature-based intelligent fan speed control, using the BP neural network to adjust PID controller parameters, thereby improving the dynamic performance of the intelligent fan system's speed control. For the intelligent fan system, a three-layer BP neural network is employed, comprising the input layer, the hidden layer, and the output layer, with a total of 32 neurons in the hidden layer (as shown in **Figure 6**).

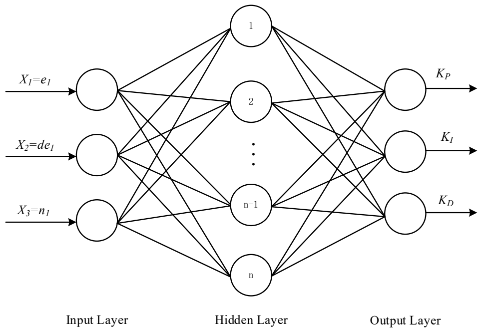

Figure 6. Three-layer BP neural network

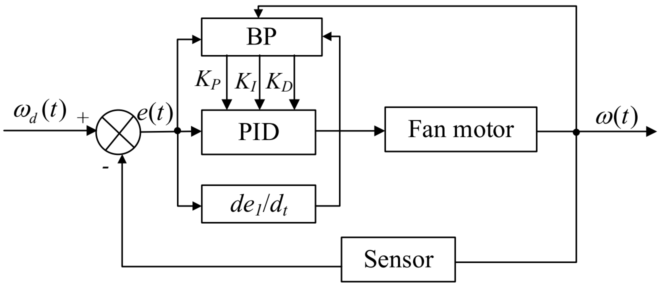

Figure 7. Temperature-based fan speed control structure

The input layer of the BP neural network:

$$M_j^1(k) = X(j)(k), j = 1,2,3 \tag{1}$$

The input to the hidden layer is as follows:

$$\begin{cases} net_1^2(k) = \sum_{j=1}^{4} w_{ij}^2(k) \cdot Q_j^1 \\ M_i^2(k) = f(net_i^2(k)) \end{cases} \tag{2}$$

The output of BP is as follows:

$$\begin{cases} net_m^3(k) = \sum_{i=1}^{Q} w_{mi}^3(k) \cdot M_i^2(k) \\ M_m^3(k) = g(net_m^3(k)), m = 1,2,3 \\ M_m^3(k) = K_P O_2^3(k) = K_I O_3^3(k) = K_D \end{cases} \tag{3}$$

4.2. Temperature-based fan speed control structure

The temperature-based fan speed control structure designed in this paper is illustrated in **Figure 7**. In **Figure 7**, $\omega(t)$ represents the output speed of the fan motor; $\omega_d(t)$ represents the desired speed designed according to the temperature; $e(t)$ represents the speed error of the fan motor. The control process of adjusting the fan speed based on temperature is as follows: firstly, the fan intelligent mode is activated, and the desired speed is given according to the ambient temperature; secondly, the fan motor speed error $e(t)$, the derivative of speed error de_1/dt, and the output speed $\omega(t)$ are used as input signals to the BP neural network. After adjusting the parameters, the control signal is outputted to the fan motor; finally, a new desired speed is given based on the feedback of the ambient temperature from the sensor, and the PID control is adjusted accordingly.

4.3. Temperature-based fan speed optimization simulation

The temperature-based fan speed control system are built in MATLAB/Simulink, and a fan speed simulation based on temperature regulation is performed, as shown in **Figures 8–11**.

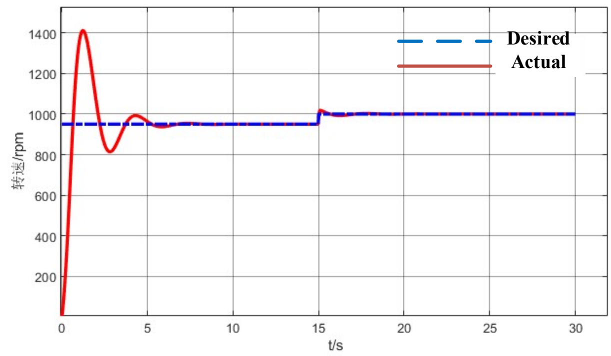

Figure 8. Temperature-based fan speed control Simulation 1

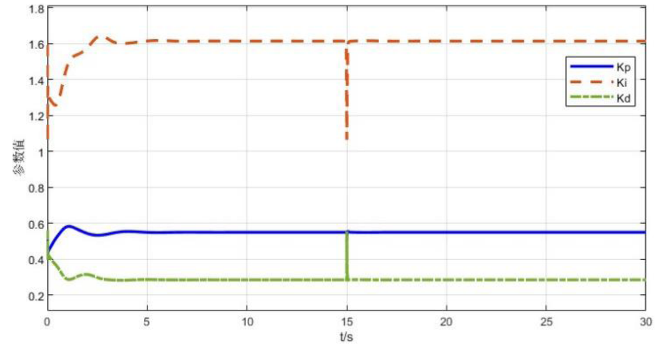

Figure 9. Simulation of temperature-based fan speed control with PID Parameters 1

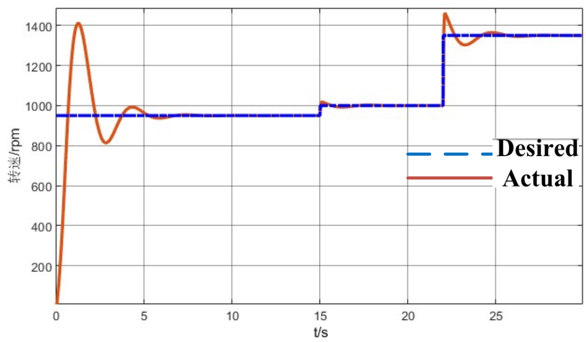

Figure 10. Temperature-based fan speed control Simulation 2

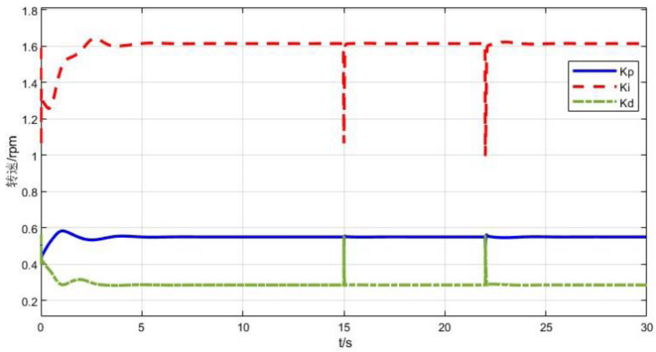

Figure 11. Simulation of temperature-based fan speed control with PID Parameters 2

The simulation results indicate that when the ambient temperature changes from 25°C to 27°C, the fan speed switches from 950 rpm to 1000 rpm; when the ambient temperature changes from 27°C to 29°C, the fan speed switches from 1000 rpm to 1350 rpm. The simulation results demonstrate that the designed temperature-based fan control system is capable of achieving smooth multi-level speed transitions even during temperature changes at multiple levels.

5. Conclusion

This study has successfully developed an intelligent fan speed control system based on indoor temperature feedback, aiming to improve energy efficiency and user comfort. Through a thorough analysis of existing fan speed control technologies, limitations in speed switching were identified. To address this issue, an intelligent control algorithm was designed and implemented, capable of dynamically adjusting fan speed based on real-time temperature changes. Experimental results demonstrate that compared to traditional fan systems, our system can achieve smoother and more efficient speed adjustments while maintaining indoor temperature stability. This not only enhances energy usage efficiency but also significantly improves user comfort experience. Additionally, the system's real-time responsiveness is crucial for adapting to constantly changing environmental conditions.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Shen Y, Meng Y, Wang R, et al., 2022, Design of Intelligent Electric Fan Based on Fuzzy Control. Journal of Xiangnan University, 43(02): 104–111.

[2] Geng M, Yin M, Wang B, et al., 2023, Intelligent Speed Control Design of Server Fan Based on Fitting Function. Mechanical and Electrical Engineering Technology, 52(06): 183–185 + 230.

[3] Deng J, He Y, 2023, Design of Intelligent Fan Control System. Electronic Production, 31(10): 41–43 + 63.

[4] D'Apice C, D'Arienzo PM, Dudin A, et al., 2023, Optimal Hysteresis Control via a Queuing System with Two Heterogeneous Energy-Consuming Servers. Mathematics, 11(21): 4515.

[5] Chen Z, Liu J, Lin Y, et al., 2023, Intelligent Humidifying Fan with Face Tracking Based on STM32. Wireless Interconnection Technology, 20(10): 41–43.

[6] Yin P, Xiao Q, Su L, 2023, Design of Intelligent Fan Control System Based on Microcontroller. Papermaking Equipment and Materials, 52(05): 37–39.

[7] Zhang S, Mo K, Luo X, et al., 2023, Research on Intelligent Fan Based on Microcontroller. Electronic Production, 31(08): 93 + 98–101.

[8] Iriho K, Mduma N, Machuve D, 2022, IoT Based Smart Fan Controller and Fire Prevention in Computer Laboratory. International Journal of Advanced Technology and Engineering Exploration (IJATEE), 9(94): 7454.

[9] Shu R, Gong H, Hu G, 2022, Novel Intelligent Fan Clutch for Large Hybrid Vehicles. Energies, 15(12): 4308–4308.

[10] Cui XR, Zhao LH, Chen G, et al., 2013, Smart Fan Design Based on PSoC. Applied Mechanics and Materials, 2560(347–350): 252–256.

[11] Hong L, Sun Y, Cao C, 2020, Motor Synchronisation Control for Multistage Hot Die Forging Press Feed Manipulator Based on BP-PID Controller. International Journal of Computing Science and Mathematics, 11(4): 347–356.

[12] Chai Z, Zhou C, Guo R, et al., 2024, Research on the Model of Scale Removal under Slurry Impact Based on BP Neural Network. JOM, 76(1): 445–451.