Automatic PLC based Server Room Cooling System

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Abstract: **In the era of digitalization, server rooms are the backbone of our interconnected world, hosting critical equipment for data processing, storage, and communication. Maintaining optimal environmental conditions in these server rooms is a challenging task due to varying workloads and consequent fluctuations in heat generation. This paper presents an innovative solution to this challenge - an Automatic PLC based Server Room Cooling System. Our system leverages cutting-edge sensors, PLC technology, and an intuitive Human-Machine Interface (HMI) to ensure real-time monitoring and precise cooling adjustments. The system integrates the TA2115 temperature sensor with the IFM CR711S controller to regulate temperature and develop control logic. It employs actuators for temperature control and a feedback mechanism for system monitoring and alerting. The system guarantees enhanced reliability and energy efficiency, safeguarding server infrastructure against overheating, and ensuring uninterrupted performance. The practical applications of this system extend to edge computing sites and industrial control rooms, demonstrating its versatility and effectiveness. This paper details the design, implementation, and expected outputs of this advanced temperature control system, highlighting its potential to revolutionize temperature management in server rooms.**

Keywords: Digitalization, Server rooms, Data processing, Automatic PLC, Server Room Cooling System, Human-Machine Interface (HMI), Real-time monitoring, Temperature regulation, ifm.

I. INTRODUCTION

In the digital age, server rooms have become the nerve centers of our interconnected world. They house sensitive equipment that is vital for data processing, storage, and communication. As the demand for data continues to grow exponentially, so does the need for more powerful servers and, consequently, more efficient server rooms. However, maintaining optimal environmental conditions in these server rooms is a challenging task due to varying workloads and consequent fluctuations in heat generation.

The performance and longevity of server equipment are highly sensitive to their operating environment, particularly the ambient temperature. Overheating can lead to hardware failure, data loss, and reduced lifespan of the equipment, leading to significant financial losses and potential reputational damage. Therefore, effective temperature management in server rooms is not just a matter of efficiency, but a critical requirement for reliable and continuous operation.

Balancing temperature control with energy efficiency is another crucial aspect. Cooling systems often account for a significant portion of a server room's energy consumption. Therefore, an efficient cooling system can contribute to substantial energy and cost savings.

This paper presents an innovative solution to these challenges - an Automatic PLC based Server Room Cooling System. Our system leverages cutting-edge sensors, PLC technology, and an intuitive Human-Machine Interface (HMI) to ensure real-time monitoring and precise cooling adjustments.

The system integrates the TA2115 temperature sensor with the IFM CR711S controller to regulate temperature and develop control logic. It employs actuators for temperature control and a feedback mechanism for system monitoring and alerting. The system guarantees enhanced reliability and energy efficiency, safeguarding server infrastructure against overheating, and ensuring uninterrupted performance.

The proposed system is designed to be flexible and adaptable, capable of responding to the dynamic needs of a server room environment. It continuously monitors the ambient temperature and adjusts the cooling intensity as needed, ensuring that the servers always operate within their optimal temperature range.

Moreover, the system provides administrators with real-time information about the server room conditions through an intuitive display interface. This allows for proactive management and immediate response to any potential issues, further enhancing the reliability of the server operations.

The practical applications of this system extend beyond traditional server rooms. It can be effectively used in edge computing sites, which are located closer to end-users to reduce latency and improve performance for real-time applications. These sites require efficient cooling solutions to maintain optimal operating conditions for edge servers and networking equipment.

Furthermore, the system can also be utilized in industrial control rooms and automation environments that rely on server-based control systems and SCADA (Supervisory

Control and Data Acquisition) systems. These environments can greatly benefit from PLC-based cooling systems to ensure stable temperature conditions for critical operations.

In conclusion, the Automatic PLC based Server Room Cooling System represents a significant advancement in server room temperature management. It combines the precision and reliability of PLC technology with the efficiency and adaptability of modern cooling systems to deliver a solution that is both effective and energy-efficient. This paper will detail the design, implementation, and expected outputs of this advanced temperature control system, highlighting its potential to revolutionize temperature management in server rooms.

II. LITERATURE REVIEW

Server room temperature control is a critical issue due to the significant impact of temperature on the reliability and efficiency of data centers. Various studies have explored different approaches and technologies to address this problem, leveraging advancements in IoT, automation, and intelligent systems.

Onibonoje et al. [1] present an IoT-based system for real-time conditioning and control of environmental factors in server rooms. Their system is designed to monitor and manage conditions such as power outages, heat, water leakage, smoke, flame, and light-out scenarios. The system implements corrective measures such as activating air conditioning when heat thresholds are exceeded, shutting off water supply during leakages, and triggering alarms in case of smoke or fire detection. Data and notifications are sent to the cloud, administrators' computers, and mobile devices to ensure timely responses to environmental changes.

Huizhou et al. [2] propose an intelligent monitoring system for server rooms that utilizes motion target detection algorithms to assess the operational status of air conditioners. By combining video monitoring with temperature and humidity sensors, the system ensures quasi-real-time detection and response to changes in environmental conditions. This approach helps maintain the desired temperature and humidity levels, addressing the unattended security needs of server rooms.

Xue et al. [3] describe an integrated operation and maintenance management system for server rooms, which employs IoT, 3D visualization, deep learning, and image processing technologies. This system provides comprehensive sensing, analysis, and management of the server room environment. It integrates various subsystems, such as security equipment and network security devices, to enhance the overall security and efficiency of server room operations. The system aims to achieve modern unattended intelligent server rooms, improving management levels and ensuring physical and network security.

Mercy et al. [4] introduce a smart window system that uses IoT to monitor and adjust the temperature in enclosed environments like server rooms. The system automatically operates appliances such as air conditioning and fans to maintain optimal temperature conditions. This system can also be controlled manually through an application, providing flexibility and remote monitoring capabilities. It helps ensure that server rooms remain at appropriate temperature levels, reducing the risk of overheating and hardware damage.

Kalpana et al. [5] focus on real-time monitoring and controlling of sub-station equipment, particularly transformers, using IoT. They employ various sensors, including ultrasonic, temperature, voltage, and current sensors, integrated with a microcontroller to monitor these parameters. The data is displayed in an Android application, enabling remote monitoring of transformer health. This system ensures the reliability of power supply by maintaining optimal conditions within transformers, which is critical for server room operations.

Zhang et al. [6] introduce an on-demand cooling system that leverages real-time thermal information from servers to optimize cooling efficiency in data centers. This system addresses limitations of traditional cooling mechanisms by providing direct feedback and quicker responses to thermal variations. By using server inlet temperature and airflow demand data, the system adjusts cooling supply in real-time, reducing temperature oscillations and enhancing cooling responsiveness. This approach supports higher operational temperatures in data centers, leading to significant energy savings.

Sharmila and Bhuvaneswari [7] develop an IoT-enabled smart cooling system for server rooms using DS18B20 temperature sensors and Raspberry Pi controllers. Their system demonstrates improved accuracy and automation in maintaining optimal temperature conditions. By continuously monitoring and adjusting the temperature, the system helps prevent hardware damage and data loss due to overheating, ensuring the smooth operation of server rooms.

Roy et al. [8] present a temperature and humidity monitoring system for industrial storage rooms using IoT. This system employs Arduino wireless sensor networks and cloud-based data storage to enhance real-time detection and ensure the longevity of stored products. The monitoring system provides a reliable method for maintaining appropriate environmental conditions, which is also applicable to server rooms. It helps in extending the lifespan of equipment and preventing data loss due to adverse environmental conditions.

The studies reviewed highlight the advancements and diverse approaches in IoT-based monitoring and control systems for maintaining optimal environmental conditions in server rooms. Common themes include the integration of various sensors, real-time data processing, and automated control mechanisms aimed at enhancing the efficiency, reliability, and security of data centers. By leveraging IoT and intelligent systems, these approaches provide significant improvements over traditional methods, offering more precise and responsive environmental management.

III. Components

A. IFM Ecomat Controller (CR711S)

Description:

- Processor: 32-bit triple core processor.
- Memory: Large application memory for extensive programming and data storage needs.
- Certification: Certified as a safety controller with support for CANopen Safety, making it suitable for applications requiring high reliability and safety standards.
- Inputs and Outputs: Scalable inputs and outputs can be configured for both standard and safety applications, providing flexibility in system design.
- Interfaces: High-performance CAN and Ethernet interfaces facilitate various communication tasks and integration with other systems.
- Programming: Freely programmable according to IEC 61131-3 standards using CODESYS 3.5, a widely-used development environment for industrial automation.
- Durability: Rated for vibration and intensive electromagnetic compatibility (EMC) interference, ensuring robust performance in harsh environments.
- Dimensions and Weight: 219 x 47 x 203 mm, 3 kg.

Applications:

- Suitable for safety-related applications in industrial automation, including server room temperature control where precise and reliable operation is critical.

B. Connecting Cable with AMP Connector (EC0710)

Description:

- Function: Ensures reliable signal transmission between controllers and modules.
- Durability: Designed for a wide operating temperature range and harsh industrial environments.
- Connector: Lockable 81-pole AMP connector with reverse polarity protection and A-coding, ensuring secure and correct connections.

Applications:

- Used to connect the Ecomat Controller (CR711S) to other components and modules within the temperature control system.

C. Ethernet Connection Cable (EVC925)

Description:

- Versions: EVC925 with 1 m PUR-Cable, M12 / RJ45 connectors.
- Protection: High protection rating suited for harsh industrial environments.
- Material: Cable sheath made of halogen-free and flame-retardant material, enhancing safety.
- Compatibility: Shielded cable ensures good electromagnetic compatibility.

Applications:

- Used for Ethernet communication between the controller and other networked devices, ensuring robust and reliable data transmission.

D. Jumper Cables

Description:

- Standards: Meets M12 and M8 standard (EN 61076) for industrial connectivity.
- Sealing: Reliable sealing even without tools, protecting connections from environmental factors.
- Vibration Protection: Nut secured against shock and vibration, ensuring stability in dynamic conditions.

Applications:

- Provides flexible and secure connections between various system components, including sensors and actuators.

E. Temperature Transmitter (TA2115)

Description:

- Precision: High precision across the entire temperature measurement range.
- Response: Excellent response dynamics and very short power-on delay time, ensuring quick and accurate temperature readings.
- Housing: Robust stainless-steel housing with a high-pressure rating and high protection rating for harsh environments.

Applications:

- Measures and monitors the temperature within the server room, providing data for the control system to maintain optimal conditions.

F. DC Motor (as an actuator for controlling temperature)

Description:

- Function: Acts as an actuator to control temperature-related mechanisms, such as fans or dampers.
- Control: Allows for variable speed control to precisely manage airflow and temperature regulation.

Applications:

- Used to adjust physical parameters within the server room to maintain the desired temperature setpoint.

G. Variable Regulated DC Power Supply (0 - 30 VDC)

Description:

- Function: Provides adjustable power to various components of the system, ensuring each receives the correct voltage for operation.
- Range: 0 - 30 VDC output allows for fine-tuning of power delivery.

Applications:

- Powers the controllers, sensors, actuators, and display units in the temperature control system.

H. Programmable Graphic Display (CR1140)

Description:

- Display: 4.3" display with robust 64-bit architecture, suitable for industrial use.
- Function Keys: RGB backlit function keys with tactile feedback for user interaction.
- Interfaces: High-performance CAN and Ethernet interfaces for communication.

- Programming: Programmable to IEC 61131-3 with CODESYS 3.5, enabling custom user interface and control logic.

Applications:

- Displays system status, alerts, and other critical information to operators, enhancing monitoring and control of the temperature system.

These components collectively form a robust and flexible system for monitoring and controlling the temperature in a server room. The IFM Ecomat Controller serves as the central processing unit, interfacing with various sensors and actuators through reliable connectors and cables. The temperature transmitter provides precise data, which is processed by the controller to adjust the DC motor's operation, maintaining optimal conditions. The programmable graphic display offers real-time feedback and control capabilities to users, ensuring the system operates efficiently and effectively.

IV. Hardware Setup

fig. 4.1 Hardware connections of components

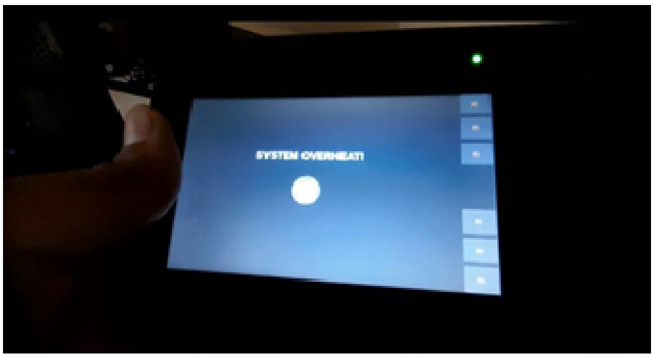

fig. 4.2 Temperature overheat alert on display

V. Block Diagram

The block diagram in fig. 5.1 illustrates a temperature control system. The system comprises a laptop with CODESYS software, which is connected to a Programmable Logic Controller (PLC, model CR711S) via a cable (ECO710) for programming and communication purposes. The PLC is powered by a DC power supply and is responsible for executing the control logic of the system.

A TA2115 temperature sensor measures the ambient temperature and sends the data to the PLC. Based on the sensor readings, the PLC adjusts the speed of a motor-driven fan in the cooling system. Specifically, if the temperature (T) exceeds a predefined threshold (Tth), the PLC increases the fan speed to cool the environment. Conversely, if the temperature drops below the threshold, the PLC decreases the fan speed to conserve energy.

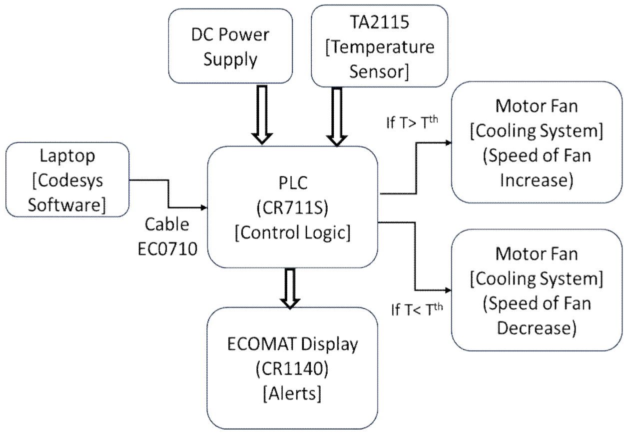

fig. 5.1 Block diagram of System

Additionally, the system features an Ecomat display (CR1140) that provides visual alerts and status information, ensuring operators can monitor system performance in real-time. The continuous feedback loop between the sensor and the PLC allows for precise temperature regulation within the desired range.

VI. Working

The Automatic PLC-Based Server Room Cooling System is designed to ensure the optimal operation of server rooms by maintaining a stable temperature, which is critical for the performance and longevity of servers and related equipment. The system employs a Programmable Logic Controller (PLC) model CR711S to automate the control of cooling fans based on temperature readings from a TA2115 temperature sensor.

The system configuration begins with setting up the PLC using CODESYS software on a laptop connected via an EC0710 cable. The PLC is programmed to execute control logic that processes inputs from the temperature sensor and controls outputs to the cooling fans. The control logic involves several key steps, starting with reading the temperature data from the sensor. The TA2115 sensor measures the ambient temperature in the server room and sends an analog signal to the PLC, which is then converted into a digital value representing the current temperature.

This digital temperature value is continuously monitored and compared against a predefined threshold of 18650 units. If the temperature exceeds this threshold, the system interprets this as a need for increased cooling, setting a control flag (xDrive) to TRUE. This action triggers the PLC to send signals to the cooling fans, increasing their speed to enhance the cooling effect. Conversely, if the temperature is below the threshold, the xDrive flag is set to FALSE, indicating that the cooling requirement is minimal, and the fan speed is reduced or turned off accordingly.

The fan speed control is managed by adjusting parameters like uiFrequency and uiValue. When cooling is required (xDrive is TRUE), these parameters are set to uiSpeed, corresponding to the desired fan speed to achieve effective cooling. When cooling is not required (xDrive is FALSE), both parameters are set to zero, stopping the fans to conserve energy and reduce wear.

The system also features an Ecomat Display CR1140, which provides real-time monitoring and alerts. This display unit shows the current temperature, fan speed, and any system alerts, allowing for immediate visual feedback and manual intervention if necessary. The PLC’s program includes routines for handling rising and falling triggers of key press and release events, ensuring robust and responsive control of the cooling system.

Communication within the system is facilitated by the CAN protocol, which ensures reliable data exchange between the PLC and other components. The CAN protocol's robustness is crucial for maintaining consistent and accurate control signals, especially in environments with high electromagnetic interference like server rooms.

Additionally, the system includes safety features such as error detection and reset capabilities for the cooling fans. These features ensure that any faults in the fan operation are promptly identified and addressed, maintaining the reliability of the cooling system.

The integration of the various components—PLC, temperature sensor, cooling fans, and display—creates a cohesive system that autonomously maintains the server room temperature within optimal limits. This automation not only reduces the need for manual monitoring and intervention but also ensures a consistent and reliable cooling performance, thereby protecting the servers from overheating and potential failure.

Future enhancements to the system could include the integration of more advanced sensors for humidity and airflow, further optimizing the cooling process. Additionally, implementing predictive maintenance algorithms could enhance the system's reliability by predicting potential failures before they occur, thus allowing for proactive maintenance.

In summary, the Automatic PLC-Based Server Room Cooling System effectively combines PLC technology, temperature sensing, and automated control to maintain an optimal server room environment. By continuously monitoring the temperature and adjusting the fan speed accordingly, the system ensures efficient cooling, energy conservation, and protection of critical server equipment. The use of CAN communication protocol and robust error handling further enhances the system's reliability and performance, making it an essential solution for modern server room management.

VII. References

[1] M. O. Onibonoje, P. N. Bokoro, N. I. Nwulu, and S. L. Gbadamosi, "An IoT-Based Approach to Real-Time Conditioning and Control in a Server Room," in 2019 International Artificial Intelligence and Data Processing Symposium (IDAP), Malatya, Turkey, 2019, pp. 1-6, doi: 10.1109/IDAP.2019.8875880.

[2] J. Huizhou, Z. Haidong, and W. Wei, "Design of Intelligent Monitoring System for Server Rooms," in 2023 IEEE International Conference on Electrical, Automation and Computer Engineering (ICEACE), Changchun, China, 2023, pp. 1-5, doi: 10.1109/ICEACE60673.2023.10442281.

[3] J. Xue, S. Wu, Z. Ji, and W. Pan, "Research on Intelligent Server Room Integrated Operation and Maintenance Management System," in 2023 2nd International Conference on Artificial Intelligence and Computer Information Technology (AICIT), Yichang, China, 2023, pp. 1-8, doi: 10.1109/AICIT59054.2023.10277803.

[4] S. M. S., A. Sivasubramanian, B. B. Natesh, J.M. Mathana, J. V. J., and G. Lokesh, "Internet of Things based Smart window and Temperature Monitoring System," in 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2020, pp. 1-5, doi: 10.1109/ICACCS48705.2020.9074365.

[5] S. Kalpana, N. Saranya, and K. Saundariya, "An IoT Based Real-Time Monitoring and Controlling of Sub-Station Equipment," in 2021 International Conference on System, Computation, Automation and Networking (ICSCAN), Puducherry, India, 2021, pp. 1-6, doi: 10.1109/ICSCAN53069.2021.9526443.

[6] S. Zhang, X. Liu, N. Ahuja, Y. Han, L. Liu, S. Liu, and Y. Shen, "On demand cooling with real time thermal information," in 2015 31st Thermal Measurement, Modeling & Management Symposium (SEMI-THERM), San Jose, CA, USA, 2015, pp. 1-6, doi: 10.1109/SEMI-THERM.2015.7100137.

[7] P. Sharmila and P. T. V. Bhuvaneswari, "IoT Enabled Smart Cooling System for Server Room," in 2021 Innovations in Power and Advanced Computing Technologies (i-PACT), Kuala Lumpur, Malaysia, 2021, pp. 1-6, doi: 10.1109/i-PACT52855.2021.9696815.

[8] A. Roy, P. Das, and R. Das, "Temperature and humidity monitoring system for storage rooms of industries," in 2017 International Conference on Computing and Communication Technologies for Smart Nation (IC3TSN), Gurgaon, India, 2017, pp. 1-5, doi: 10.1109/IC3TSN.2017.8284459