Automation of Cooling System for Variable Frequency Drive

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***Abstract*—The Automation of Cooling System for Variable Frequency Drive (VFD) project aims to enhance the efficiency and reliability of industrial processes by implementing an intelligent cooling system for VFDs. VFDs are widely used in industrial applications to control the speed of electric motors, thus optimizing energy consumption. However, efficient cooling is crucial for maintaining the optimal performance and longevity of VFDs. This project introduces an automated cooling system that dynamically adjusts the cooling parameters based on the operating conditions of the VFD. The system utilizes sensors to continuously monitor the temperature, load, and environmental conditions. An intelligent control algorithm processes this real-time data to optimize the cooling process, ensuring that the VFD operates within the recommended temperature range. This project introduces an innovative solution by automating the cooling system associated with VFDs. The core objectives are to enhance operational reliability, energy efficiency, and system longevity through intelligent control and monitoring mechanisms. VFD generates heat during operation due to the power electronics and switching mechanisms involved in converting and controlling electrical energy. The cooling fan in a VFD panel helps to remove heat and maintain the temperature of the VFD. In current situation when fault occur in cooling fan of VFD then temperature of system increases up to 60 degree and then control system gives the alarm that fault in cooling system. When temperature increases up to 60 degree it may damage the power cards present in the system. The two-cooling fan present in the each VFD. Also, current system presents in the VFD not detect the exact location of faulty fan. To check the which fan is faulty operators disassemble the VFD and manually check which fan is faulty. V In this project develop automation in cooling system this gives the result when fault occur in the fan immediately gives the alarm and notification to the operator's mobile app and main computer. Also, it gives exact location of faulty fan. The data off fan status is stored in the Excel sheet in main computer. This project protects the power cards present in the VFD panel. Also, it reduces the operator's effort to checking the faulty fan.**

***Index Terms*—Variable Frequency Drive, Automation, Cooling Fan, Industry.**

I. INTRODUCTION

Variable frequency drives (VFDs) are electronic devices that manipulate electrical current to electric motors to control speed and torque. In industrial settings, VFDs are used to funnel AC power, convert it into DC power, and temporarily store converted current until it is needed. A variable- frequency drive (VFD, or adjustable-frequency drives, adjustable-speed drives, variable-speed drives, AC drives, micro drives, inverter drives, or drives) is a type of AC motor drive (system incorporating a motor) that controls speed and torque by varying the frequency of the input electricity. Depending on its topology, it controls the associated voltage or current variation. A variable frequency drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage of its power supply [1]. The VFD also has the capacity to control ramp-up and ramp-down of the motor during start or stop, respectively. With VFDs, the motor's rotation speed is controlled via the frequency of the input voltage before it is supplied to the motor. The first action of the AC drive is converting 60 Hz, 3-phase AC power to DC before inverting the DC power into a pseudo-three-phase variable frequency that goes directly into the connected motor. The frequency approaching the electric converter is 60 Hz, but the one going out of the converter into the motor has an adjustable variable frequency for achieving the required motor speed. The converter and the inverter form the two main parts of the PWM AC drive. The AC power line constitutes a three-phase power system that powers the converter [2]. The AC power lines operate at 60 Hz frequency. The converter utilizes a rectifier to convert the 60 Hz AC input into DC output voltage. The DC output delivered by the electric converter is rough; therefore, smoothening methods must be used to ensure a more or less constant output DC voltage. This filtering action occurs between the stages of conversion and inversion. After smoothening, the DC is sent directly into the inverter stage. The purpose of the inverter section is to produce AC output that is tapped to drive the motor. The negative and positive switching occurs in the inverter, resulting in a collection of pulses. The PWM drive output frequency is controlled by injecting positive pulses on one of the half cycles and negative pulses on the half cycle that follows the first.

The proposed system is a fully automated fault detection of cooling system in Variable Frequency Drive. It highlights the optimum solution for the efficient use of Variable Frequency

Drive. Automate the Variable Frequency Drive cooling system to prevent overheating and minimize operator effort in order to address these defects. The current sensor identifies the specific fan that is malfunctioning and sends a signal to the operator's smartphones when a defect occurs in any one of the fans, causing it to stop operating. Once the operator received the message, the malfunctioning fan was replaced, and the Variable Frequency Drive continued to operate as before [3].

II. BLOCK DIAGRAM OF THE SYSTEM

In this system basically two parts are important, first one is taking input fan is on or off and second one is connecting the input from the hardware system to the operator's mobile app and main control computer.

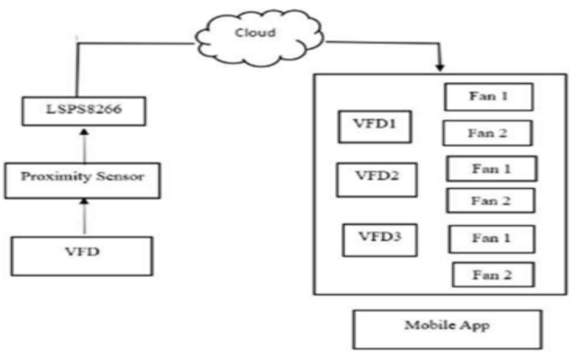

Fig.1 System block diagram

In the Fig.1 fan in variable frequency drive is connected to the current sensor. Current sensor gives the status of the fan to the PIC Microcontroller. PIC Microcontroller convert the signal in the form of digital signal and send to the ESP32. The Wi- Fi module ESP32 connect the input given from the current sensor to the operator mobile through Wi-Fi.

III. COMPONENTS FOR THE SYSTEM

There are many components which are useful for this project. According to the working and their properties selected the appropriate components which are useful for the project and significant for the industrial application. Current sensor gives the rotation of fan within seconds. So, that this sensor is best for this project. ESP32 is the best wi-fi module compare the other wi-fi module. These chosen components are affordable and simple to install in the industrial setting.

A. Current Sensor (ACS712)

Without making physical contact, a current sensor may identify the presence of things in the immediate vicinity. A linear current sensor module that measures both AC and DC currents is the ACS712, which is based on the Hall effect. The Hall effect is used by the ACS712 module to measure current. A magnetic field corresponding to the current is created when it passes through the conductor. This magnetic field is detected by the chip's Hall-effect sensor, which then generates a voltage proportionate to the current.

Fig. 2 Hall Effect ACS 712 Sensor

Fig.2 shows the current sensor. The ACS712 current sensor produces an analog voltage proportional to the current passing through the conductor and comes in 5A, 20A, and 30A versions, each of which is intended for a certain current range. It is appropriate for both AC and DC current measurements since, at zero current, the output is approximately 2.5V (assuming a 5V supply). Depending on the current range, sensitivity varies by model, with the 5A version having a sensitivity of 185 mV per amp, the 20A version having a sensitivity of 100 mV per amp, and the 30A version having a sensitivity of 66 mV per amp. The ACS712, which is built using Hall-effect technology, improves safety by providing electrical isolation between the load and the output, particularly when interacting with delicate parts or microcontrollers. Although some variants are compatible with 3.3V systems, it usually requires a 5V supply, making it adaptable for a range of monitoring applications.

B. ESP32

Fig. 3 shows the A strong and adaptable microcontroller is the ESP32. Because of its great performance, low power consumption, and wide range of peripheral and protocol support, it is frequently utilized in Internet of Things (IoT) applications.

The ESP32 microcontroller has a dual-core Xtensa LX6 CPU that can run at up to 240 MHz; certain variants can only handle one core. It normally has 448 KB of ROM and 520 KB of SRAM, while some models can also include external memory.

Fig. 3 ESP32(Microcontroller)

It is appropriate for Internet of Things applications that need numerous wireless connections because it supports Bluetooth 4.2, including BLE, and Wi-Fi (802.11 b/g/n). It has 36 GPIO pins and can interface with sensors and devices in a variety of ways thanks to features like PWM, ADC (12-bit), DAC (8- bit), I2C, SPI, and UART. It has multiple modes, including deep sleep at as low as 10 µA for battery efficiency, and is made for low-power operation.

For magnetic and temperature detection, some versions come with an integrated Hall-effect sensor and temperature sensor. Programming the ESP32 is flexible for all skill levels and may be done with the Arduino IDE, ESP-IDF. For further connectivity, it also supports Ethernet (with an external PHY), CAN, and I2S. The ESP32 is available in a number of modules, such as the ESP32-WROOM and ESP32-WROVER series. It can be configured with external RAM or internal flash memory, which expands its processing and storage capacity for a variety of uses.

C. Display

The Fig.4 shows an electronic device called a display serves primarily as an interface to show the reading, or information, that results from a certain computer or electronic circuit operation.

Fig.4 Display

In this project, liquid crystal displays, or LCDs, are used. The twisted nematic effect principle is the name of its operating mechanism. The electric field may cause the unique liquid crystal molecules to align in one of two states: voltage off or voltage on.

D. PCB Layout

The Fig.5 shows a printed circuit board, also known as a printed wiring board (PWB), is a type of board that is used in circuits to wire or connect various components to one another. It takes the shape of a sandwich structure made of conductive and insulating layers that has been laminated together. Each conductive layer is patterned with traces, planes, and other elements that resemble wires on a flat surface. These features are etched from one or more copper sheet layers that are laminated onto and/or between sheet layers of a non- conductive substrate.

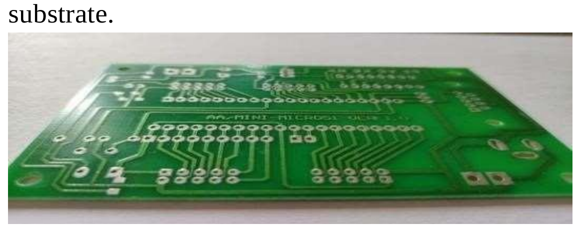

Fig.5 PCB Layout

Electrical components can be physically and electrically fastened to conductive pads on the outer layers by soldering them to the pads in the shape intended to receive the component's terminals. Vias, plated-through holes that enable connectivity between layers, are added during a different manufacturing process.

E. Buzzer

A buzzer Fig.6 shows other auditory signaling device can be mechanical, piezoelectric, or electromechanical in nature. This is mostly used to convert the audio signal to sound. It is often powered by DC voltage and found in computers, printers, alarm clocks, timers, and other devices. It can produce a variety of sounds, including alarm, music, bell, and siren, according on the varied designs.

Fig.6 Buzzer

The main function of buzzer is converting signal from the audio sound and it is used for the alarm when fault occur in the system.

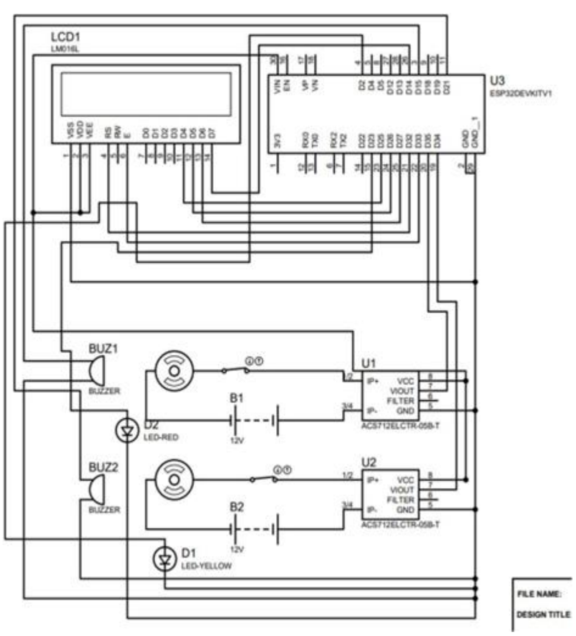

Fig.7 Circuit Diagram of Automation of Cooling System

IV. WORKING OF THE SYSTEM

The current sensor identifies the specific fan that is malfunctioning and sends a signal to the operator's smartphones when a defect occurs in any one of the fans, causing it to stop operating.

Once the operator received the message, the malfunctioning fan was replaced and the Variable Frequency Drive continued to operate as before. VFD may overheat if the cooling system's fan stops operating because of a blockage of dust or another issue. In order to do this, we place the current sensor next to the cooling fan.

V. VFD COOLING SYSTEM: SOFTWARE

Wi-Fi Device Selection

Connect the ESP32 to your microcontroller or development board (e.g., Arduino) using appropriate pins (TX, RX, VCC, GND). Ensure the proper power supply and wiring connections. Install USB Drivers (if using a USB-to-

Serial converter) If you're using a USB-to-Serial converter for programming, install the required drivers. Install Arduino IDE Open Arduino IDE Go to File - Preferences and enter the following URL in the "Additional Boards Manager URLs" field: Go to Tools Board Boards Manager, search for" esp32" and install the ESP32 board package. Select ESP32 Board Choose the correct ESP32 board model from Tools Board menu. Set Upload. Speed and Port Set the upload speed and select the appropriate COM port from the Tools menu [7].

Write and Upload Code Write your Wi-Fi code using the Arduino IDE. Upload the code to your ESP32. Monitor Serial Output Open the Serial Monitor in Arduino IDE to view debug information and check if the ESP32 is connecting to the Wi-Fi network. Verify Connection Ensure that the ESP32 successfully connects to the specified Wi-Fi network.

The appropriate Wi-Fi devices that are suited for the project in terms of hardware connections and software is main part of the project. The wi-fi device connect the hardware model which gives the signal to the cloud. Through the wi-fi device result is display in the operator mobile app and main computer system. The program code is something have created for the wi-fi module name and password for the security. Flowchart is developed for the fan on and off status. Also Developed codes are useful for the ESP8266 Wi-Fi connection and cooling fan malfunction detection.

VI.TESTING AND RESULT

A buzzer may sound and the operator will be alerted when a real fault arises in the VFD. Via the app, the operator's smartphone can also view a graph showing how the cooling fan operates.

Fig.8 Fan status of fan 1 Vs Time

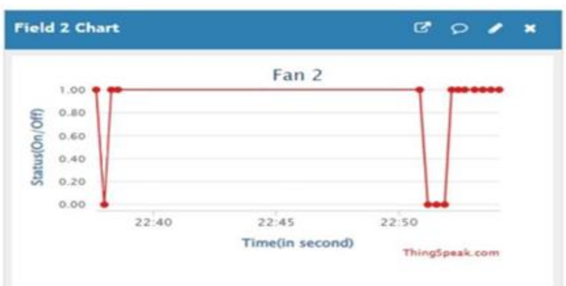

Fig.9 Fan status of fan 2 Vs Time

The Fig. 8 and Fig.9 shows the graph of Fan status Vs time of Fan 1 and Fan 2 respectively. When the fault occurs and fan stop then graph falls from the 1 to 0 and will remains 0 until the fault occurs in the cooling fan of VFD.

The fan status vs. time graph is displayed in the figures. These results are display in an operates mobile app and main control computer. After testing it is known that developed automation in cooling system for variable frequency drive gives the exact location of faulty fan. Immediate gives the alarm and notification to the operator mobile app and main computer when fault occur in fan and fan is in off state

VII. CONCLUSION

Variable frequency drive is a system designed to control the speed of motor according to the load demand. VFD generates heat during operation due to the power electronics and switching mechanisms involved in converting and controlling electrical energy. The cooling fan in a VFD panel helps to remove heat by circulating air over the sinks or cooling elements within the VFD. Various faults occur at this cooling system like voltage fluctuation, current variation and jamming of cooling fan due to dust particles. To overcome these faults, we develop automation of Cooling System in VFD. In our project the relay installed in the circuit which placed in the VFD will trip and sound an alert if a malfunction occurs in the cooling fan. Then with his smartphone, the operator is able to determine precisely which fan is faulty. When the fan is turned off because of a failure, the current sensor's use allows for fast problem detection. As a result, the malfunctioning fan can be identified without raising the VFD's temperature. Power cards in VFD are hence secure. Developed system is used for the where multiple cooling fan is used.

VIII. FUTURE SCOPE

In the future, advanced sensors for real-time monitoring, machine learning algorithms for predictive maintenance, and energy-efficient cooling options to improve system performance could all be included in the automation of a cooling system in a variable frequency drive (VFD). For remote monitoring and control, compatibility with cutting-edge technologies like cloud-based platforms and the Internet of Things may also be taken into consideration.

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