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IoT Based SCADA System for Substation Monitioring

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Abstract— The rapid advancements in automation have revolutionized various industries, particularly in electronics and power systems. This project presents a cloud- assisted IoT-based SCADA (Supervisory Control and Data Acquisition) substation monitoring and alert system designed to enhance efficiency, reliability, and remote accessibility. The proposed system monitors critical parameters such as temperature, voltage, and current using dedicated sensors. These analog sensor readings are converted to digital values via an Analog-to-Digital Converter (ADC) and processed by a microcontroller. The system features an LCD for real-time parameter display and a buzzer that activates when predefined threshold limits are exceeded. Additionally, remote monitoring and control capabilities are enabled through a Wi-Fi module, allowing users to access data from any location. The primary advantages of the system include high-speed response, broad sensor connectivity, and seamless remote operation through advanced communication protocols. While automation enhances efficiency, it also poses challenges such as potential job displacement. The system is implemented using hardware components such as an Arduino UNO, sensors, relays, and communication modules, with software support from the Arduino IDE and Embedded

C. This innovative SCADA system provides a cost-effective and scalable solution for substation monitoring and management.

Keywords: Substation Monitoring, SCADA Security, Alert System, Embedded Systems, IoT, Arduino UNO

I. INTRODUCTION

SCADA SYSTEM

"Supervisory control and data acquisition system"(SCADA) is a technology which enables user to collect data from far off locations in power system and to send control commands whenever necessary to these locations

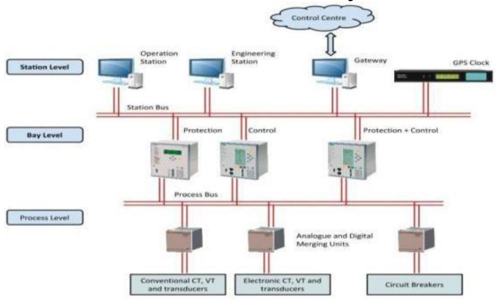

Fig. 1: The Digital Substation

These systems enable automation of large electrical substations by providing effective monitoring and control functions. The automation tasks involved include data acquisition, supervision and control. Signals gathered from far off remote places include status indication, analog values, alarms, and totalized meter values among other signals types. Typical signals sent from SCADA systems are usually limited to discrete binary bit changes or to analog values addressed to a device at a process. Fig. 1 shows a digitalized substation.

INTERNET OF THINGS

The Internet of Things, refers to the network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and connectivity, enabling them to connect and exchange data. These connected devices can communicate with each other and with humans, creating a vast net work of inter connected systems. IoT has numerous applications across various domains, including smart homes, healthcare, transportation, agriculture, and industrial automation. It enables automation, data collection, analysis, and remote control, leading to improved efficiency , convenience ,and insights .In simpler terms, IoT connects everyday objects to the internet, making them "smart" and capable of interacting with us and each other. It's like having a world where everything is interconnected and can work together to make our lives easier and more efficient.

SCOPE AND OBJECTIVES

This project proposes to design an IoT-based SCADA system at low cost for real-time substation control and monitoring. Sensors are used for measuring critical parameters such as voltage, current, frequency, temperature, and humidity. Over current and abnormal voltage faults are sensed, which initiate alarms and relay- based load isolation. A 16x2 I2C LCD shows real-time on- site display, and ESP8266 facilitates wireless data transfer to a remote server. The system mimics fundamental SCADA capabilities with Arduino UNO and low-cost components. Strong coding facilitates automatic recovery from communication or sensor failure. Easy control logic governs relay operation both automatically and manually. Transmission of data is executed with AT commands for effective communication. The system is expandable for educational, rural, or small industrial substations. It also increases practical insight into embedded systems and IoT in power systems..

II. SYSTEM DESCRIPTION

The given system is an IoT-based SCADA-based substation control and monitoring system that combines sensor-based data acquisition with wireless communication for real-time performance monitoring. The system centers around using an Arduino UNO microcontroller, which serves as the main processing unit in charge of communication with sensors and communication modules. It employs an ESP8266 Wi-Fi module to provide wireless connectivity, allowing live substation data to be transmitted to a web-based monitoring portal.

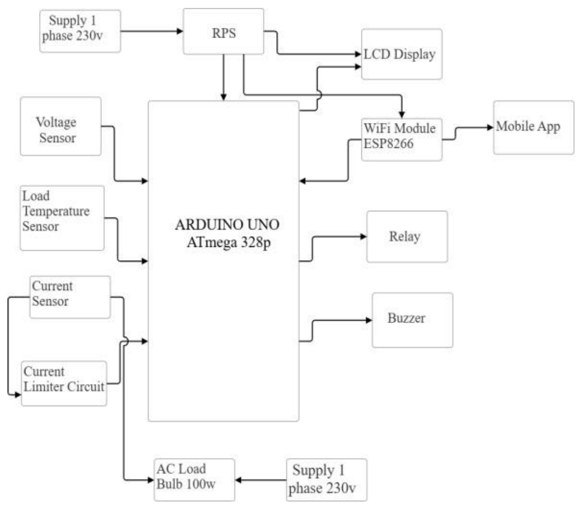

Fig 2 Block Diagram of proposed system

To monitor important substation parameters, the system utilizes a potential transformer (PT)/ voltage sensor and a current transformer (CT) attached to analog input pins A1 and A2 of the Arduino, respectively. The devices allow real-time monitoring of voltage and current readings. The environmental conditions are also monitored through a DHT11 sensor that gives readings for temperature as well as humidity. The data measured is shown locally on a 16×2 I2C-based Liquid Crystal Display (LCD), demonstrating real-time voltage, current, frequency (simulated) and temperature updates. The system further consists of a buzzer and relay circuit, which are triggered due to faulty conditions like overcurrent (more than 2 A) or voltage out-of-limit conditions outside the safe limit range of 180 V to 250 V. Under these circumstances, the system automatically switches off the associated load by deactivating the relay and warns the adjacent personnel via the buzzer.

Communication with the ESP8266 by the Arduino is achieved through SoftwareSerial, which ensures that data is transferred smoothly without disrupting the main serial port of the Arduino. The ESP8266 is controlled through AT commands to work in station mode and connect to a Wi-Fi network. After successful connection, the module begins an HTTP server, which allows external access to the parameters being monitored via a web browser. The system sends and formats data as a string through TCP/IP commands, providing effective remote data transmission.

All the functionalities are brought about through the Arduino IDE, with required libraries for sensor communication and serial transmission. The system can not only monitor but also undertake preventive control measures in the event of any observed anomalies. The low-cost, scalable, and flexible nature of this design presents a real-world solution to the improvement of conventional substations into intelligent, remotely accessible ones, aiding in smart grid infrastructure development.

III. WORKING PRINCIPLE

The suggested system works based on real-time monitoring and control of electrical parameters in a single-phase substation setup through an Arduino UNO-based SCADA system with the integration of IoT capabilities. The Arduino UNO microcontroller (ATmega328p) is the core of the system, which accepts analog input signals from voltage sensors and current sensors to read real-time electrical quantities. A DHT11 sensor is utilized to sense the temperature of the substation and aid in thermal safety control. The sensed values are initially processed using the Arduino, which checks if the measured values are within safety operating ranges. When the current is higher than 2A, or the voltage is lower than 180V or higher than 250V, the system will instantaneously send safety warnings.

A buzzer is engaged to produce a local sound alarm, and a relay is de-activated to cut off the load, hence safeguarding attached devices against electrical faults or damage.

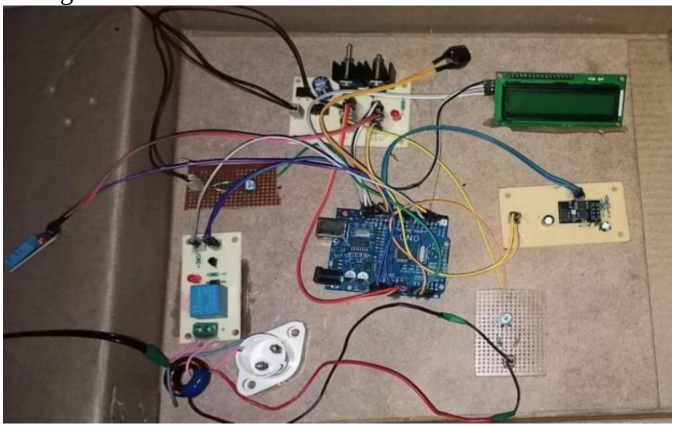

Fig 3 Proposed model of IoT based SCADA System for Substation Monitoring - Stage 1

In parallel, the system leverages the ESP8266 WiFi module to set up a wireless link to the internet. After connection, the module uploads processed information to a distant cloud server and provides access to users via a cell phone application. This facilitates remote monitoring and data recording, which are essential in preventive maintenance and fault diagnosis in substations. The LCD display gives local indication by displaying real-time values of voltage, current, frequency (simulated), and temperature, assuring transparency and ease of monitoring even in the field. This smart automation minimizes human intervention and increases the responsiveness and safety of the electrical distribution system. The project not only enables contemporary SCADA usage but also aids in the establishment of smart grid infrastructure by combining local sensing with analytics in the cloud

Benefits:

The solar-based safety stick provides several advantages:

- ➢ Supports monitoring of voltage, current, frequency, and temperature parameters in real- time in substations.
- ➢ Provides real-time alerts for overvoltage, undervoltage, and overcurrent situations through IoT.
- ➢ Enhances reliability and safety by tripping relay and buzzer in case of fault conditions.
- ➢ Eliminates manual inspection and improves remote control using mobile app connectivity

IV. RESULTS AND DISCUSSIONS

The hardware setup of the SCADA-based IoT substation monitoring system was tested successfully, as evident from the image. Accurate real-time voltage, current, and temperature values were displayed on the LCD, and fault conditions accurately triggered the buzzer and relay control.

The system showed efficient remote monitoring through the ESP8266, proving its functionality and practical feasibility.

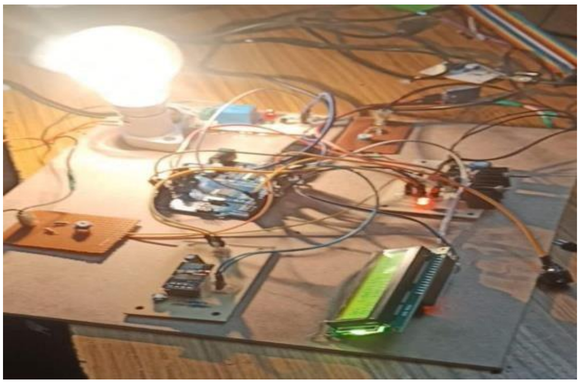

Fig 4 Proposed model of IoT based SCADA System for Substation Monitoring - Final Stage

Fig 5 LCD Display

This verifies that the system is indeed sensing and showing substation parameters correctly. The responsiveness and clear readability of the display assure the correct operation of the Arduino and sensor integration.

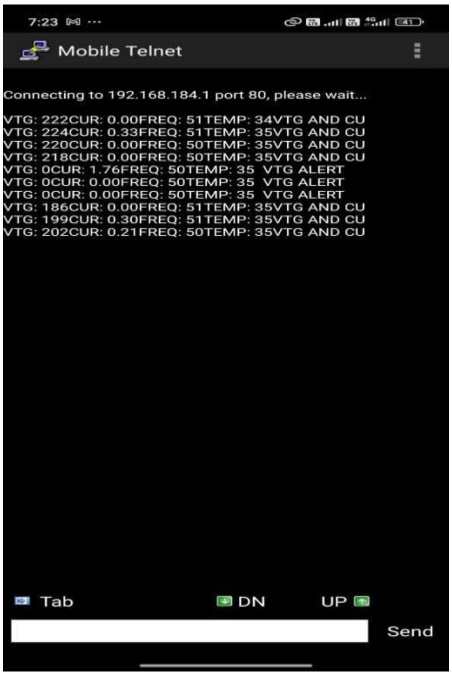

Fig: 4 Alert received in Mobile

V. CONCLUSION

The IoT-based SCADA substation monitoring and control system effectively integrates Arduino, ESP8266, DHT11 sensor, and LCD for monitoring essential parameters such as voltage, current, temperature, and frequency in real-time. The system continuously analyzes the CT and PT sensor readings to detect abnormalities such as over current and voltage fluctuations. Upon detecting abnormalities, it triggers specific actions like relay activation/deactivation and alert notifications via the buzzer. Additionally, it sends data to the ESP8266 module for remote monitoring over WiFi, displaying the IP address for easy access. The LCD provides immediate visual feedback, ensuring that the operator is promptly informed about the system status. While the system is cost-effective and scalable, it is vulnerable to network disruptions and lacks advanced data processing capabilities. Addressing these limitations through enhanced security protocols, data encryption, and integration with cloud analytic can further strengthen the system's functionality and reliability.

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