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A Comprehensive Study of the Effectiveness of Microcontroller-Based Monitoring Techniques for the Supervision of Substations

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ABSTRACT

Rapid revolutions in different fields of science, industries and technologies offer the advantages of using AVR microcontrollers based on monitoring systems designed and deployed to detect, diagnose and measure disturbances in the circuit.

The AVR microcontroller monitoring system will make it possible to monitor defects at many points immediately for more extensive systems and devices such as motors and power devices.

AVR Microcontroller monitors and controls a substation voltage, current, and temperature in a distribution transformer by detecting overload, high current and high temperature. The measured values of the transformer's voltage, current, and temperature will be transmitted via the RF transmitter every time. Through RF transmission, the output being monitored will be presented on a computer located at the central station in a remote location. Distribution transformer parameters are compared to rated values and shut down the transformer to protect and enhance its work. So the AVR microcontroller is a protector, quality enhancer and reliability improver.

Keywords: Substations Distribution Transformers Microcontroller Generators Electricity Power transmission systems.

1.INTRODUCTION

Electricity is a highly advantageous and valuable form of energy. It's becoming more critical in industrialized society. Electrical energy systems exhibit significant non-linear characteristics [1], characterized by their vast size and complicated network structures. These electric power systems are integrated to achieve cost-efficiency, enhanced dependability, and operational benefits. Infrastructure systems are pivotal in national and global contexts, holding enormous significance. The collapse of such systems has far-reaching consequences, directly and indirectly impacting financial matters and security [2]. A power grid comprises various elements, including generators, transmission lines, transformers, loads, switches, and compensators. The overall design of newfangled energy systems typically involves a broad spectrum of sources of energy and loads [3]. Electrical energy systems are generally categorized into two distinct subsystems: transmission and distribution. The essential process of transmission systems transfers energy from power plants to end-users, in addition to distribution systems connecting high-voltage transmission networks to users' ends. Providing electrical energy to end users requires the essential processes of power generation, transmission, and distribution. Electric power is mainly produced by utilizing electric power sources, including but not limited to nuclear power generators, thermal power generators, and hydraulic power generators. Subsequently, this power is transmitted via transmission systems employing high voltage. After leaving the generator's location, the energy flows to a transmission substation equipped with enormous transformers that high voltage from the generator to levels suitable for long-distance transmission (up to approximately 300 miles). Afterwards, the voltage is lowered through the use of transformers and power is distributed to clients through electric power distribution systems. The generated power comes from the transmission grid and is transmitted to distribution substations. At these substations, the voltage is reduced (usually below 10kv) and conveyed through smaller distribution lines to carry to the demands of residential, commercial, and industrial consumers [4]. Modern electrical energy systems encompassing power transmission and distribution grids comprise many distributed, autonomously managed, capital-intensive assets. The assets in question encompass the following components:

1.) power generation facilities.

2.) electrical conductors for transmitting power.

3.) devices for transforming electrical energy.

4.) equipment designed to safeguard the system.

Electric substations have triple tasks, transmission, distribution, and operation of standalone electricity production. A specific building does these tasks with a fenced-in yard comprising many components, including tracking circuit voltage regulators, transformers, switches, and metering equipment. The distance between electric power generation stations and consumption areas (loads) varies by station type. The central generation stations, for example, are hundreds of miles away.

Nevertheless, the backup stations are closer to the consumption zones. Long-distance complications can lead to interruption of the power system as a result of defects in the electric power quality. Hence, The power system feeding quality is based on voltage quality and the non-technical consideration of the electrical energy network's interaction with its loads. The growing need for energy in various industries drives upward electricity demand. Moreover, an immense amount of generating power will be minimized at the received substation as a consequence of energy transmission.

Recently severe defects have appeared on the power grids as a result of rapid variations in the power quality. So that customers have identified issues caused by this power quantity. As a result, fault detection should be diagnosed at least from one end of a faulted part, like a transmission line; in fact, only specific devices can detect these faults through recording data like meagre devices accessible at specific substation positions. The instability of the power system has derived from incomplete protection, monitoring, or control, so there must be a monitoring system to diagnose faults and classify electrical line defects to enhance the power quality. This elucidates the benefits for both end users and utility entities [5]. Typically, distributed control agents are utilized to provide reactive control at multiple locations on the power system using various devices, including but not limited to:

1.) Power system stabilizers (ps)

2.) Automatic voltage regulators (vars)

3.) Flexible ac transmission systems (facts) and other similar components

Monitoring systems record every pertinent information in a local database. Additionally, power transformer safety needs comprehensive and systematic monitoring. The initial stages of power transformer breakdown can be detected by effective monitoring, enabling condition-based maintenance rather than relying solely on periodic scheduling. In recent years, numerous research efforts have been conducted utilizing microprocessors and controllers that allow continuous monitoring of sample ingredients. These studies additionally investigated the behaviour of analysts at various time intervals [6], as well as monitoring voltage, current, and temperature disturbances in distribution transformers located at substations.

The variation in temperature at the distribution transformers can lead to significant fluctuations in the levels of current and voltage observed at the substations. Consequently, the power delivered to the user may not meet the required quality standards. Thus, monitoring current, voltage, and other necessary parts at the distribution side can enhance the output generated at the central station and the quality of power supplied to the customer. Additionally, it can detect and identify problems resulting from excessive load, elevated temperature, and overvoltage. The monitoring system will safeguard the distribution transformer by triggering a unit shutdown if the temperature rises above the optimal threshold. As mentioned previously, the maintenance of transformers poses a significant challenge for the electricity board. The transformer experiences burnout because of overload and short circuit conditions within its range. These unusual events lead to the breakdown of the transformer. Likewise, the temperature of the oil rises due to the heightened current flow within their internal windings. As mentioned earlier, the phenomenon leads to an unforeseen voltage, current, or temperature increase within the distribution transformer. Providing electrical energy to end users requires the essential processes of power generation, transmission, and distribution [7]. Electric power is mainly produced by utilizing electric generators, including but not limited to nuclear power generators, thermal power generators, and hydraulic power generators. Subsequently, this power is transmitted via transmission systems employing high voltage. After leaving the generator's location, the energy flows to a transmission substation equipped with enormous transformers that high voltage from the generator to levels suitable for long-distance transmission (up to approximately 300 miles) [8]. Afterwards, the voltage is lowered through the use of transformers, and power is distributed to clients through the use of electric power distribution systems. Hence, we propose the implementation of automation for the distribution transformer located at the substation. In terms of industrialization, the parameters that are deemed crucial for monitoring are voltage, current, and temperature. This is due to the fact that the transformer exhibits its highest level of sensitivity towards these particular parameters. Therefore, we have developed an automation system utilizing a microcontroller that performs continuous transformer monitoring. Due to the functioning of the microcontroller, the transformer located in the substation is deactivated at the primary station. The subsequent sections of the paper are organized as follows. Section 2 provides a concise overview of various methodologies found in existing literature for the purpose of monitoring power in distribution systems. In section 3, the strategy, along with its algorithm for tracking and controlling the vital ingredients of distribution transformers employing the system based on a microcontroller, is presented. This is done with the support of the system.

2. Related works

The reconstruction process in the domain of the electric power industry leads to a demand for creative approaches for displaying a large quantity of system data. This requirement is caused by the process of rebuilding.

Over bye and Weber [9] offered a synopsis of several unique visualization techniques that could be fairly useful for depicting the data. Utilizing styles such as contouring, animation, data aggregation, and virtual environments is immensely helpful. However, important challenges remain. The two most significant obstacles are as follows: 1.) The difficulty of expressing not only the current situation of a working system additionally The potential of an immense amount of immediate situations, and 2.) The challenge is assessing the impact of many planned power transfers rather than simply one. Both of these problems are extremely difficult to solve.

In their study [10], Johan Driesen and colleagues clarify an adaptable system of energy model of measurement, which involves a DSP in addition to sensors and communication elements. This system is utilized by the contemporary electricity distribution systems, which are characterized by the presence of many suppliers operating in a market that has been deregulated, bi-directional energy flows as a result of dispersed generation, and a diverse range of demands for the quality of electricity transmission.

Several aspects of the network, namely signal processing, communication, and reliability, were dissected in this article. The instances of the employment of such technologies shown in their work are also included. Transientmeter is a monitoring system designed and deployed by Daponte et al. to detect, categorize, and measure disturbances in the electricity system. The Transientmeter, wavelet-based signal categorization and characterization, and an intelligent stimulate circuit for disturbance identification use CORBA architecture for communication. The categorization and measurement of disturbances were carried out with the assistance of a wavelet transform and a network-based measurement technique. Humberto Jimenez et al. discussed the 18-month distribution transformer monitoring outcome. The transformer fed multiple residences with grid-connected photovoltaic systems, and its power factor was strangely low. This occurrence can lead to the truth that, in certain situations, the network provides a significant proportion of the active power required by households. At the same time, the grid is responsible for supplying the reactive and distorted powers.

The utilization of the operating temperature served as an indicator of the pressure produced on the transformer. The temperature reached its minimum point when the systems were operating at a maximum generation of electricity from the cells that produce sunlight. Mathematical Morphology (MM) in electrical quality monitoring systems rapidly detects irregularities. However, disturbances often distort the signal, degrading the MM's performance. Sen Ouyang and Jianhua Wang developed a fast method for the diagnosis of intermittent fluctuations in environments.

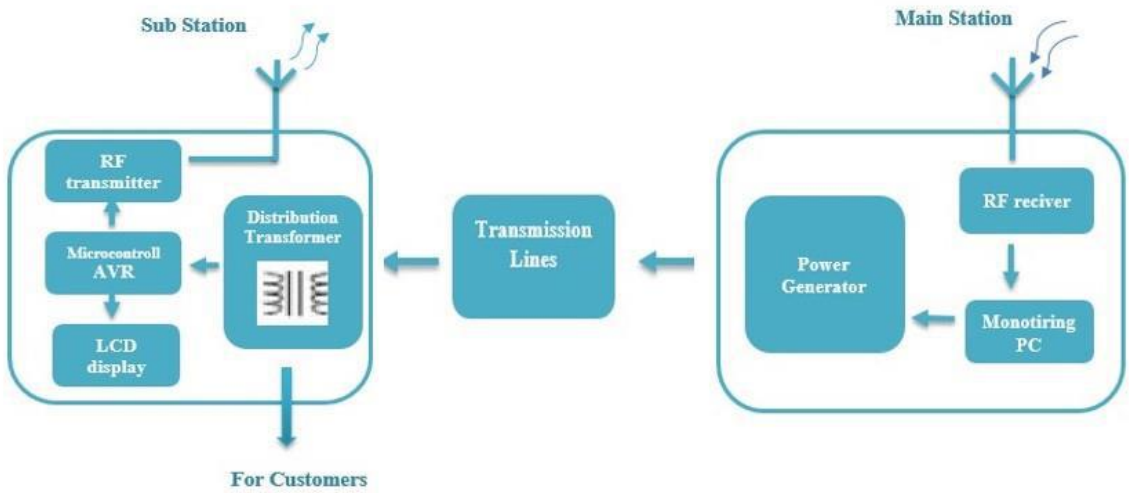
With the present technique, the suitable morphologic, structural component, erosion, and dilation morphologic operators can improve MM. For reference, Wavelet Transform (WT) soft-threshold denoising was utilized. MM abilities can be regained—benefits of this method: Fast calculation, easy hardware implementation, and improved usage value. Finally, the simulation and field experiments validate the proposed method. Loads that are nonlinear and temporally variable cause several disruptions in the energy grid, from considerable distortion of currents and voltages to transient supply voltage disturbances. The electric network acts as a "healthy carrier" of disturbances. Thus, a customer's disturbance might spread to other customers and damage their equipment. In a deregulated power market, where each component of an AVR Microcontroller can introduce disturbances, evaluating a network section's electric power quality is essential. Power-quality measurement has various methodological and instrumental issues that demand careful analysis. Alessandro Ferrero [11] has analyzed these issues and proposed methods for improving the current research. Power quality monitoring requires advanced data handling and processing.

Despite significant storage and processing improvements in microprocessor-based monitoring systems, these constraints limit monitoring. The following two approaches are among those in which creating more efficient algorithms will enhance the quality of power.: 1.) They will make it possible to monitor more points concurrently for bigger networks, and 2.) Tracking systems will make it easier to construct strong monitoring architectures that can be embedded within smaller electrical energy devices, like breakers, motors, or power drives. Antonio Ginart and colleagues have suggested that the distance L1 standard be used as a measure of the power supply's overall quality. They have demonstrated how their technique has increased the demand for computing power as well as storage space. Their study has offered three things: 1.) Analysis of the suggested norm; 2) How it differed from previous methodologies; and 3.) Instances of its applicability.

3. Suggested AVR Microcontroller System for Substrate Control and Monitoring

If an overload or a substantial current passes through the transformer's internal winding, distributed transformers are vulnerable to damage because the oil temperature rises. An increase in oil temperature raises the opportunity for transformer damage. The transformers must be watched over extremely carefully in these sorts of situations. A monitoring unit that is connected to the distribution transformer for the sole purpose of monitoring that transformer is included in the system that has been proposed. As a result, to solve the previously described issue, we have devised a simulation model that explains in great detail how the system works. The monitoring system is comprised of three main components, which are as follows: 1. Data processor/transmitter 2. Load-Measurement Systems 3. Receiver/PC display unit.

AVR-based microcontrollers monitor and control a substation's voltage, current, and oil temperature distribution transformer. RF communication will display the monitored output on a remote main station PC. Distribution transformer parameters are compared to rated values. Overload and high voltage failures are detected and sent to the main station via RF transmission. The PC software makes comparative the obtained readings with the distribution transformer's rated measurements and shuts down the transformer to protect it and improve performance. The controller's sensing unit measures the distribution transformer's current, voltage, and oil temperature. The processing unit's digital display shows substation technical operations' parameter values. The controller detects overload and excessive current flowing in internal windings that may cause unit failure. The microprocessor scans the transformer, and values are updated at a set interval. The microcontroller's RF transmitter sends the parameter values it senses. The signals that have been broadcast are picked up by the RF receiver located at the central station. After that, the signals that were received are sent to the PC. Variations in distribution transformer specifications can be monitored using software loaded into the personal computer (PC). When it detects an important variation in the monitored values, it takes control of the apparatus and stops it from sustaining any significant damage.



3.1. The Principle of the Microcontroller System Is Suggested in The Present Work.

The Variables of the transformer's voltage, current, and temperature are instantaneously supplied into Port A, which is one of the input ports that the microcontroller use. Additionally, an interface for a display is built within the microcontroller's Port B, which functions as an additional input port. Port C, one of the microcontroller's output ports, is interfaced with both the RF transmission module and the load variation control mechanism. Port C's function is to control load variation. The central station is accessible via the monitoring PC's interface. The microcontroller located at the substation performs monitoring of a designated time interval, capturing and logging data about current, voltage, and temperature within said timeframe. The acquired measurements are subsequently Kept in the values register before being presented on the LCD. The RF transmitter disseminates the measured values of the monitored voltage, current, and transformer temperature during each specified interval. The antenna must be tuned to transmit a signal at the desired radio frequency (RF). However, the antenna must possess a structure of single-directional radiation. The reception antenna of the suggested network is responsible for receiving data transmitted by the transmitter. The receiver antenna transmutes radio frequency (RF) signals into electrical energy. The data will serve as a guiding factor for the operation Is performed. If the receiver receives transformer characteristics above the fixed threshold level, the units are turned down to protect them

3.2. Design Procedures

Setting up the interface parameters for the LCD and the Data Registers is necessary. Following are the microcontroller-based system's design stages. Assign numerical identifiers to the various components within the circuit, including the Relay, denoted as Component 1; the LED, designated as Component 2; the Buffer, labelled 3; and the Fan. Carry out the necessary steps to set up all ports of the microcontroller. The mechanism of action is defined to document the current, voltage, and temperature values that are called and carried out when appropriate. In this step, the displaying function will be called, and the values of the variables are shown. To send the captured values, the RF transmitter function is called. The LCD feature is activated to show the parameter values. While beginning the LCD, the following actions must be taken: READ, WRITE, and ENABLE. The LCD actions are carried out by using the values of hexadecimal shown below. Clear the display screen using 0X01. 0x0C =display on, cursor off; 0x38 =2 lines; 0x06 =increment cursor (shift cursor to the right); and 0x80 =force cursor to the beginning of the first line. The characters and string values are shown on the LCD using a 5*7 matrix.

The algorithms that are responsible for the operation of the controller are based on a retry mechanism. This mechanism performs a continuous scan of the variables and displays the current status in the display unit. The following procedures are outlined below. Are carried out, and the appropriate parameters' values are noted so that it can be established whether or not the transformer is operating in a risk-free setting. The LCD

and RF transmission modules' interface ICs connect the microcontroller. Data processing units support interface efficiency. Interface settings start the microcontroller-peripheral device connection. The register values for Ports C and D are set to "1" within the main program's infinite loop, indicating that these ports are set up as output ports. After that, the microcontroller's data register is filled with the required parameter values when the capturing routines are executed. The information in the data registers will be communicated via radio frequency transmission to a computer in the control centre. Now, the functions of the RF transmitter are called and carried out by the PC through the data that have been sent. The recorder values are set up and assigned based on the operation to be performed, either READ or WRITE. The transmitter data are set up to zero before sending buffer values.

After the values have been sent, the data in the buffer are overwritten to make room for the newly captured values. Parameter values are shown by activating the LCD function. The initialization process of the LCD involves three primary operations: READ, WRITE, and ENABLE. The hex values provided are utilized for the execution of LCD operations.

If the code 0X01 appears on the screen, it means to erase all content. Display on, cursor off (0x0C), two lines (0x38), the pointer increments (+06) when moved to the right (0x80), and the first line is always selected (80). The liquid crystal display (LCD) employs a 5x7 matrix to present characters and string values.

4. Conclusion

An overview is applied to the suggestion of a microcontroller that works as an electrical quality monitoring system that rapidly detects faults in the circuit by a data processor, transmitter, and receiver.

The mechanism of action of this system located in the substation is performing the continuous scan and monitoring of designated time intervals, capturing and logging data about current, voltage, and temperature.

The main benefits achieved from the microcontroller and monitoring system are to enhance both qualities of the generator at the centre station and the quality of power supplied to the user end, as well as improve protection by turning down circuit components if the receiver receives transformer characteristics above the fixed threshold level. So microcontroller systems truly enhance efficiency, safety, and reliability.

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