AN EFFICIENT MONITORING OF SUBSTATIONS USING MICROCONTROLLER BASED MONITORING SYSTEM

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ABSTRACT

The paper proposes an innovative design to develop a system based on AVR micro controller that is used for monitoring the voltage, current and temperature of a distribution transformer in a substation and to protect the system from the rise in mentioned parameters. Providing the protection to the distribution transformer can be accomplished by shutting down the entire unit with the aid of the Radio frequency Communication. Moreover the system displays the same on a PC at the main station which is at a remote place. Furthermore it is capable of recognizing the break downs caused due to overload, high temperature and over voltage. The design generally consists of two units, one in the substation unit, called as transmitter and display unit, and another in the Main station called as controlling unit. The transmitter and the display units in the substation is where the voltage, current and temperature are monitored continuously by AVR microcontroller and is displayed through the display unit. An RF transmitter is used for transmitting the signals that are obtained. The controlling unit in the main station by means of a PC and a RF receiver receives the RF signals that are transmitted by the Transmitter unit and reacts in accordance to the received signal. In general, the proposed design is developed for the user to easily recognize the distribution transformer that is suffered by any open or short circuit and rise in temperatures. The ultimate objective is to monitor the electrical parameters continuously and hence to guard the burning of distribution transformer or power transformer due to the constraints such as overload, over temperature and input high voltage. If any of these values increases beyond the limit then the entire unit is shut down by the designed controlling unit

Keywords: *Electricity, Power Transmission systems, Substations, Distribution Transformers, Generators, Microcontrollers.*

1. INTRODUCTION

Electricity is an extremely handy and useful form of energy. It plays an ever growing role in our modern industrialized society. The electrical power systems are highly non-linear [23], extremely huge and complex networks [22]. Such electric power systems are unified for economical benefits, increased reliability and operational advantages [19]. They are one of the most significant elements of both national and global infrastructure, and when these systems collapse it leads to major direct and indirect impacts on the economy and national security [2]. A power system consists of components such as generators, lines, transformers, loads, switches and compensators. However, a widely dispersed power sources and loads are the general configuration of modern power systems [3].

Electric power systems can be divided into two sub-systems, namely, transmission systems and distribution systems. The main process of a transmission system is to transfer electric power from electric generators to customer area, whereas a distribution system provides an ultimate link between high voltage transmission systems and consumer services [15]. In other words, the power is distributed to different customers from the distribution system through feeders, distributors and service mains [21]. Supplying electricity to consumers necessitates power generation, transmission, and distribution [4]. Initially electric power is generated by using electric generators such as: nuclear power generators, thermal power generators and hydraulic power generators and then transmitted through transmission systems using high voltage. Power departs from the generator and enters into a transmission substation, where huge transformers convert the generator's voltage to extremely high voltages (155kV to 765 kV) for long-distance (up to about 300 miles) transmission [4]. Then, the voltage level is reduced using transformers and power is transferred to customers through electric power distribution systems. Power starts from the transmission grid at distribution substations where the voltage is stepped-down (typically to less than 10kV) and carried by smaller distribution lines to supply commercial, residential, and industrial users [4]. Novel electric power systems encompassing of power transmission and distribution grids consist of copious number of distributed, autonomously managed, capital-intensive assets. Such assets comprise: 1.) power plants, 2.) transmission lines, 3.) transformers, and 4.) protection equipment [1].

Electric utility substations are used in both the transmission and distribution system and operate independently to generate the electricity. A typical substation facility consists of a small building with a fenced-in yard that contains transformers, switches, voltage regulators, and metering equipment that are used to adjust voltages and monitor circuits [4]. A reliable and efficient process of these networks alone is not very significant when these electricity systems are pressed to their parameters of its performance, but also under regular operating conditions. Generators and loads are some components that coerce the continuous dynamic behavior [5].

The distance between the Generators and loads may be in terms of hundreds of miles. Hence, the amount of huge power exchanges over long distances has turned out as a result of the lack of quality of the electric power. During the earlier development stages the issues on quality of power were not frequently reported. Quality of supply is a mixture of both voltage quality and the non-technical features of the interaction from the power network to its customers [18]. Demanding the quantity of power being delivered at the user side has raised the alarm due to the increase in demand of electricity in the customer's side. The power generated at the main stations is transported hundreds of miles using transmission lines before they reach the substations. A huge amount of power is lost during the transportation of the generated power which leads to the reduction in the quantity of power received at the substations. Also the electric lines users have identified that the number of drawbacks caused by electrical power quality variations are increasing rapidly. These variations have already existed on electrical systems, but recently they are causing serious problems [6]. Therefore, measurements must be acquired either from one end or from both the ends of a faulted line. Only meager recorded data is available at limited substation locations in certain systems. When a fault occurs in such systems, only a few (two or three) recording devices are triggered. The most likely case is that the measurements could not be obtained at either or both ends of the faulted transmission line [16] leads to drop in the quality of the power.

To improve the quality of power with sufficient solutions, it is necessary to be familiar with what sort of constraint has occurred. Additionally, if there is any inadequacy in the protection, monitoring and control of a power system, the system might become unstable [20]. Therefore, it necessitates a monitoring system that is able to automatically detect, monitor, typify and classify the existing constraints on electrical lines. This brings up advantages to both end users and utility companies [6]. In general, distributed control agents are employed to offer reactive control at several places on the power network through the devices namely: 1.) Power System Stabilizers (PSSs), 2.) Automatic Voltage Regulators (AVRs), 3.) FACTS and much more [3]. Monitoring systems offers an opportunity to record each and every relevant value that is present in a local database [7]. An effective and well-organized state of monitoring is much significant in guaranteeing the safe running of power transformers. Potential breakdown of the power transformers can be recognized in their incipient phases of development by an excellent state of monitoring so that the maintenance of the power transformers can be condition based in addition to periodically scheduled [8].

During the past years a number of researches were undergone with the help of microprocessors and controllers for continuous monitoring of sample concentrations, the behavior of analysts at different time intervals [17], monitoring the voltage, current and temperature fluctuations in the distribution transformers at the substations. The level of current and voltage at the substations may vary drastically due to the increase in temperature at the distribution transformers. Due to this the quality of power being delivered to the user might be insufficient. Hence monitoring the current, voltage and additionally required parameters at the distribution side can aid in developing both the output generated at the main station and the quality of power being delivered at the customer side. It is also capable of recognizing the break downs caused due to overload, high temperature and over voltage. If the increase in temperature rises higher than the desirable temperature, the monitoring system will protect the distribution transformer by shutting down the unit.

As discussed earlier, maintenance of a transformer is one of the biggest problems in the Electricity Board (EB). During strange events for some reasons the transformer is burned out due to the over load and short circuit in their winding. Also the oil temperature is increased due to the increase in the level of current flowing through their internal windings. This results in an unexpected raise in voltage, current or temperature in the distribution transformer. Therefore, we are proposing the automation of the distribution transformer from the EB substation. In the automation, we consider the voltage, current and temperature as the parameters to be monitored as the transformer shows its peak sensitivity for the same. Hence, we design an automation system based on microcontroller which continuously monitors the transformer. Because of the microcontroller operation, the transformer present in the substation which is turned off in the main station. The rest of the paper is structured as follows. Section 2 presents a brief review of several approaches that are available in the literature for monitoring of power in distribution systems. Section 3 presents the technique along with its algorithm for monitoring and controlling the essential parameters of the distribution transformers using the system based on microcontroller. Section 4 details the three case studies analyzed in the paper and section 5 presents the conclusion.

2. RELATED WORKS

The process of rebuilding in the field of electricity industry results in a need of innovative techniques for representing a huge quantity of system data. Overbye and Weber [9] have presented a summary on various visualization techniques that might fairly be helpful for the representation of the data. The techniques such as: 1.) contouring, 2.) animation, 3.) data aggregation and, 4.) virtual environments must prove to be quite useful. Yet, important challenges remain. The major challenges are: 1.) the problem of visualizing not just the state of a existing system but also the potentially huge number of incident states, and, 2.) the problem of visualizing not just the impact of a solitary proposed power transfer but of a great number of such transactions.

Johan Driesen et al. [10] have discussed the model of an flexible energy measurement system consisting of a DSP, sensor and communication units. The modern electricity distribution networks utilizes this system, featured by multiple suppliers in a deregulated market, bi-directional energy flows owing to the distributed generation and a diversified demand for the quality of electricity delivery. Different features of the system relating to signal processing, communication and dependability were discussed. Their work also includes the examples of the use of such devices.

Daponte et al. [6] have discussed the design and implementation of Transientmeter, a monitoring system for the detection, classification and measurement of disturbances on electrical power systems. CORBA architecture is utilized as communication interface by the Transientmeter, wavelet-based techniques for automatic signal classification and characterization, and a smart trigger circuit for the detection of disturbances. A measurement algorithm, developed by using the wavelet transform and wavelet networks, had been adopted for the automatic classification and measurement of disturbances.

The results that are obtained after the process of monitoring a distribution transformer during a period of 18 months was described and discussed by Humberto Jimenez et al. [11]. The transformer fed several households, each with a grid connected photovoltaic system, and it was identified that the power factor at the transformer attained strange low levels. This was because of the fact that under some circumstances, the systems offers a great portion of the active power that is demanded by the households, whereas the grid supplied all the reactive and distortion powers. The operating temperature was used as an indicator for the pressure on transformer. The temperature level was least when the systems were providing the maximum energy available from the solar cells.

Power quality monitoring systems are capable of detecting disturbances by means of Mathematical Morphology (MM) very quickly. Yet, the signal under examination is frequently corrupted by noises, and the performance of the MM would be greatly degraded. Sen Ouyang and Jianhua Wang [12] have presented a quick process in order to detect the transient disturbances in a noisy atmosphere. In this approach, the suitable morphologic structure element, appropriate mixture of the erosion and the dilation morphologic operators can develop the capability of MM. In addition, the soft-threshold denoising technique based on the Wavelet Transform (WT) was used for purpose of reference. Thus the abilities of the MM can hence be restored. This technique has possessed the following merits: 1.) Great speed in calculation, 2.) easy implementation of hardware and, 3.) better use value. At last, the validity of the proposed technique is demonstrated by the outcome of the simulation and the actual field tests.

The propagation of non-linear and time-variant loads leads to a copious number of disturbances on the electric network, from an extremely significant distortion of both currents and voltages, to transient disturbances on the supply voltage. In this respect the electric network behaves as a “healthy carrier” of disturbances, so that a disturbance generated by single customer can be distributed to other customers, causing possible damages to their equipment. Evaluating the quality of the electric power that is present in a network section is consequently becoming an impelling requirement, mainly in a deregulated electricity market, where every actor can be in charge for the injection of disturbances. Yet, there are several respects of power-quality measurement, from both the methodological and instrumental point of views that are been unsolved yet and needs to be analyzed cautiously. An analysis of these problems and various suggestions about the development of the present research work on this area has been presented by Alessandro Ferrero [13].

Real-time monitoring of power quality necessitates great abilities of data-handling and data-processing. These requirements limit the possibility of monitoring, in spite of the fact that microprocessor-based monitoring systems have observed vital development in their storage and computational power. Development of compact algorithms will benefit power quality in the following two ways: 1.) they will allow monitoring of more points simultaneously for large systems, and, 2.) they will help in building powerful embeddable monitoring architectures within small power devices, such as a breaker, motors, or power drives. Antonio Ginart et al. [14] have proposed the use of the distance L1 norm as an indicator of power quality. They have shown how their approach has enhanced the computational and storage requirements. Their work has presented: 1.) analyses of the proposed norm, 2.) how it compared with traditional approaches, and, 3.) examples of its applications.

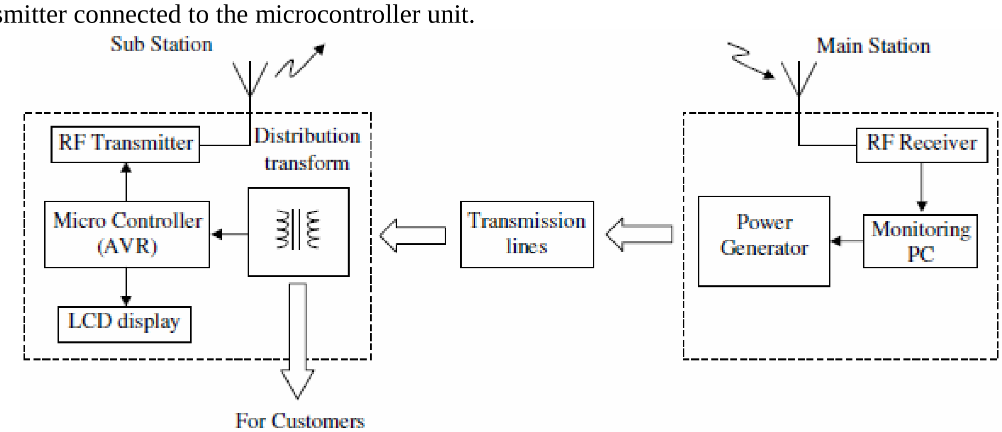
3. PROPOSED MICROCONTROLLER BASED SYSTEM FOR SUBSTATION MONITORING

Distributed transformers are prone to damages due to the raise in oil temperature when there is an overload or huge current flows through the internal winding of the transformer. When the oil temperature rises, it increases the probability of getting damages in the transformers. The transformers are to be monitored very cautiously during these situations. The proposed system consists of a monitoring unit that is connected with the distribution transformer for the purpose of monitoring the same. Hence, we introduce a simulation model which details the operation of the system to rectify the mentioned problem. The monitoring system is constituted by three major units, namely,

1. Data processing and transmitter unit
2. Load and Measurement Systems
3. Receiver and PC display unit

We have designed a system based on microcontroller (AVR) that monitors and controls the voltage, current and oil temperature of a distribution transformer present in a substation. The monitored output will be displayed on a PC at the main station that is at a remote place, through RF communication. The parameters monitored at the distribution transformer are compared with the rated values of the transformer. Additionally the breakdowns caused due to the overload and high voltage are sensed and the signals are transmitted to the main station using RF communication. The software in the PC compares the received values with the rated measurements of the distribution transformer and shuts down the transformer so that it can be prevented from damages and performances can be enhanced quiet to a remarkable level.

The controller consists of a sensing unit which collects the essential parameters such as current, voltage and the oil temperature within the distribution transformer. The digital display connected to the processing unit displays corresponding parameter values at the substation for any technical operations. The controller also senses the overload and high current flow conditions in the internal windings that may lead to breakdown of the corresponding unit. The microcontroller is programmed in such a manner so as to continuously scan the transformer and update the parameters at a particular time interval. The parameter values sensed by the microcontroller are transmitted through the RF transmitter connected to the microcontroller unit.



The transmitted signals are received at the main station using the RF receiver. The received signals are then passed to the PC. The software loaded in the PC is used to monitor the changes in the parameters that are measured from the distribution transformer. When a remarkable change is noticed in the measured values it controls the unit by ending it from any serious damages.

3.1. Monitoring and controlling by the proposed system

The values of voltage, current and temperature of the transformer is directly applied to Port A (one of the input ports of the AVR microcontroller). Along with this, a display is connected in the Port B (another input port of the microcontroller). The RF transmitting section and the load variation control are connected to the Port C (one of the output ports in the microcontroller). The monitoring PC is connected to the main station. The microcontroller at the substation monitors and captures the current, voltage and temperature values for a particular period of time interval. The captured values are stored in the data register and displayed using the LCD display.

The monitored voltage, current and temperature values of the transformer are transmitted using the RF transmitter for each and every time interval. Any antenna tuned for the selected RF frequency can be utilized for the transmission of the RF signal but the antenna has to exhibit a unidirectional radiation pattern. In the receiver side of the proposed system, the receiver antenna converts the RF signal into electrical signal and acquires the information which has been transmitted by the transmitter. Based on the received information, controlling operation is performed. If the receiver receives the transformer parameters which is greater than the fixed threshold level, then immediately the units is shutdown so as to protect the same.

3.2. Design Procedures

The design procedures for the proposed microcontroller based system is described as follows

- Define the interfacing parameters for LCD and Data Registers.
- Assign a value for the circuit elements such as Relay, LED, Buffer and Fan.
- Initialize the input and output ports of the microcontroller.
- The functions defined for capturing the current, voltage and temperature values are called and executed.
- The displaying function is called and the parameter values are displayed.
- The captured values are transmitted by calling RF transmitter function.

The controller programs is based on rip up and retry mechanism for scanning the parameters continuously and displays the current status in the display unit. The procedures stated below are performed and the parameter values are captured to check whether the transformer is operating under safe condition.

The microcontroller is connected to the LCD and RF transmission modules through their respective interfacing ICs. The apt operation of the interfaces are maintained and carried out with the help of data processing unit. Interfacing parameters are defined in order to initialize the communication between the microcontroller and the peripheral devices. In the main program an infinite loop is executed and the values for registers of Ports C and D are set as '1' i.e.; the ports are initialized as output ports. Then the capturing functions are executed and the values of the required parameters are captured and stored in the microcontrollers data register.

The values stored in the data registers are to be transferred to the PC present at the main station for further controlling operations using RF communication. Now RF transmitter functions are called and executed through the values that are transferred to the PC. Register values are initialized and assigned whether to perform READ or WRITE function. The transmitter values are initialized to zero before transmitting the values from the buffer. Once the values are transmitted the buffer values are cleared to store the next captured values.

The LCD function is initialized in order to display the parameter values. The three major operations to be performed while initializing the LCD are: READ, WRITE and ENABLE. The following hex values are used to perform the LCD operations 0X01= clear the display screen 0x0C =display on, cursor off 0x38 =2 lines and 0x06=increment cursor (shift cursor to right) and 0x80= force cursor to beginning of 1st line. The LCD uses a 5*7 matrix to display the characters and string values.

4. CASE STUDY

In order to analyze the efficiency of our microcontroller based monitoring system, we applied three various types of load at the output of the distribution transformer and transformer's operating parameters were calculated. Then the received parameters were analyzed with the transformer's rated values.

Case (i): The transformer was made to work under usual condition and no additional load is applied to the transformer. During this condition the received parameters were below the rated values of the testing transformer, thus confirming safe operation of entire unit. Under this condition, our monitoring procedures were only executed and the relay was kept in the closed position to allow power distribution. The oil's temperature was normal, the current and voltage level were very efficient and maintained normally.

Case (ii): When a small increase in the load was applied to the transformer it was observed that there was a small increase in the oil temperature and, the current and voltage values sensed by the controller was high. This change was due to the gradual increase in the level of oil's temperature. Here the measured parameters of current, voltage and temperature were under the safety level. So there was no change in the relay position. This stage also confirmed the safe operation of substation unit with a lower degree of risk.

Case (iii): In this case a heavy load was applied to the transformer and parameters were measured. Since the applied load was higher than the testing transformer's rated load the value of current, temperature and voltage also increased to a greater value. The measured parameters exceeded beyond the rated values. Now PC at the main station sends the required control signal indicating that the respective substation transformer is in a dangerous situation. Then the relay is unlocked, so that the substation unit completely shuts down. Thus the distribution transformer was protected from any damage.

The performance of the proposed system has been examined with three various types of loading which has been added to the transformer. From the experimental observations it can be understood that, the proposed system monitors and controls the transformer in an efficient manner. When a sudden rise in temperature was sensed by the system while monitoring the transformer, it directs the main station to shutdown the transformer and thus it guards the unit from any serious damages.

5. CONCLUSION

In this paper we have presented a design of a system based on AVR microcontroller that is used to monitor and control the voltage, current and temperature of a distribution transformer. The proposed system which has been designed to monitor the transformer's essential parameters continuously monitors the parameters throughout its operation. If the microcontroller recognizes any increase in the level of voltage, current or temperature values the unit has been made shutdown in order to prevent it from further damages. The system not only controls the distribution transformer in the substation by shutting it down, but also displays the values throughout the process for user's reference. This claims that the proposed design of the system makes the distribution transformer more robust against some key power quality issues which makes the voltage, current or temperature to peak. Hence the distribution is made more secure, reliable and efficient by means of the proposed system.

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