GSM-Based Distribution Transformer Monitoring System

Abdul-Rahman Al-Ali, Abdul Khaliq & Muhammad Arshad
School of Engineering, American University of Sharjah
Box 26666, AUS, Sharjah, United Arab Emirates
Email: {aali, akhaliq, marshad}@ausharjah.edu

Abstract — **This paper presents design and implementation of a mobile embedded system to monitor and record key operation indictors of a distribution transformer like load currents, transformer oil and ambient temperatures. The proposed on-line monitoring system integrates a Global Service Mobile (GSM) Modem, with stand alone single chip microcontroller and sensor packages. It is installed at the distribution transformer site and the above mentioned parameters are recorded using the built-in 8-channel analog to digital converter (ADC) of the embedded system. The acquired parameters are processed and recorded in the system memory. If there is any abnormality or an emergency situation the system sends SMS (Short Message Service) messages to designated mobile telephones containing information about the abnormality according to some predefined instructions and policies that are stored on the embedded system EEPROM. Also, it sends SMS to a central database via the GSM modem for further processing. This mobile system will help the utilities to optimally utilize transformers and identify problems before any catastrophic failure.**

I. INTRODUCTION

Distribution Transformers have a long service life if they are operated under rated conditions. However, their life is significantly reduced if they are overloaded, resulting in unexpected failures and loss of supply to a large number of customers thus effecting system reliability. Overloading and ineffective cooling of transformers are the major causes of failure in distribution transformers. Most power companies use Supervisory Control and Data Acquisition (SCADA) system for online monitoring of power transformers but extending the SCADA system for online monitoring of distribution transformers is an expensive proposition.

Distribution transformers are currently monitored manually where a person periodically visits a transformer site for maintenance and records parameter of importance. This type of monitoring can not provide information about occasional overloads and over heating of transformer oil and windings. All these factors can significantly reduce transformer life.

A number of techniques are currently being used for offline as well as online monitoring of power transformers [1-6]. Most power companies do online monitoring of their power transformers that involve Partial Discharge monitoring, recording their load conditions, gas-in-oil and moisture analysis etc. All these measurements provide useful data for monitoring and diagnostics. Later this data is transmitted to the onsite or off-site control room via a dedicated communication link or SCADA system [2-4]. However no work has been reported on the online monitoring of distribution transformer.

Online monitoring of key operational parameters of distribution transformers can provide useful information about the health of transformers which will help the utilities to optimally use their transformers and keep the asset in operation for a longer period. This will also help identify problems before any catastrophic failure which can result in a significant cost savings and greater reliability.

Widespread use of mobile networks and GSM devices such GSM modems and their decreasing costs have made them an attractive option not only for voice media but for other wide area network applications.

This paper describes the design of a monitoring system that consists of a GSM modem that is integrated with stand alone single chip embedded system to monitor and record key operation indictors of a distribution transformer like load currents, transformer oil and ambient temperatures. The paper is organized as follows; section two discusses the proposed hardware architecture, the embedded software algorithm is described in section three and section four has the experimental results. Conclusion and future is worked discussed in section five.

II. HARDWARE ARCHITECTURE

The system hardware has four hardware modules as shown in Figure 1: embedded system, GSM modem, mobile-users and GSM networks and PC-based server. The embedded module is located at the transformer site. It is utilized to acquire, process, display, transmit and receive the parameters to/from the GSM modem. The second is the GSM module. It is the link between the embedded system and the public GSM network. The third is utility module that has a PC-based -server located at the utility control center. The server is attached to GSM modem and receives/transmits SMS from/to the transformer site via the GSM module. Detailed specifications and functions of each module are described as follows:

- Embedded system module has two blocks: Signal Conditioning Circuit (SCC) block and Controller block. The SCC block reads the currents, voltages, temperatures from sensors.

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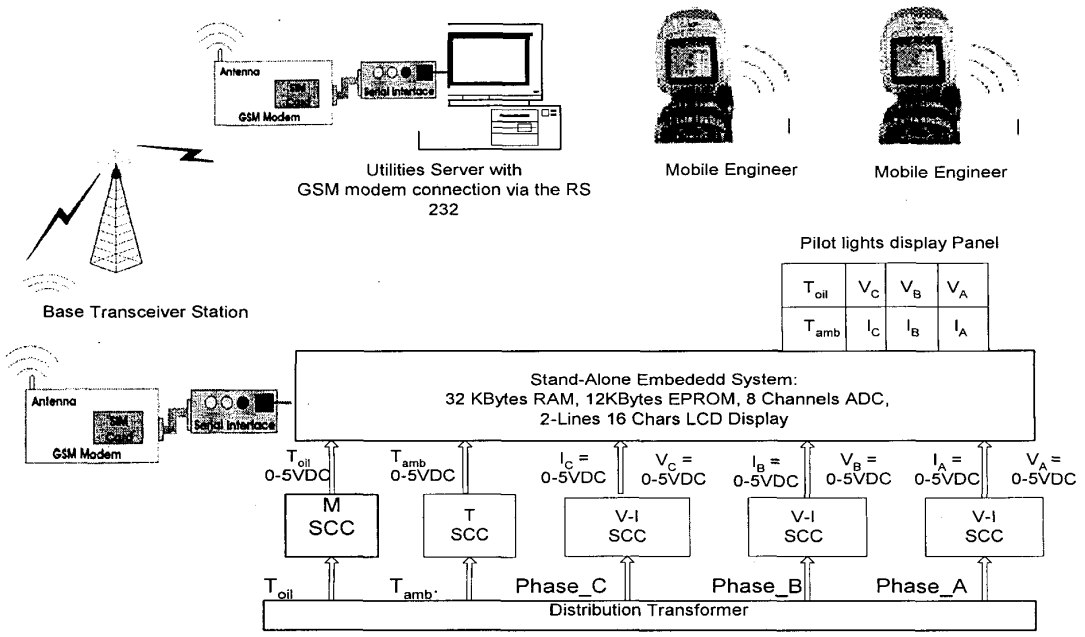

Figure 1. System hardware architecture

Then it converts each reading to a compatible signals that can be read by the embedded system built-in ADCs (0-5 volts DC). Each circuit has two Op Amps and set of resistors to adjust the gain and the offset. The current and voltage SCC have small transformers and rectifier circuits that convert and scale the current and voltage values to compatible levels with the Op Amps circuits.

- The controller block consists of an 8-bit microcontroller that has 8-channel analog to digital converter (ADC) and several digital input/output ports [7]. The ADC is used to read the parameters, the built-in EPROM is used to host the embedded software algorithm that takes care of the parameters acquisition, processing, displaying, transmitting and receiving. The built-in EEPROM is used to save the online measured parameters along with their hourly and daily averages. The system is equipped with 2-lines 16 characters/each LCD and 16-LEDs that are used as pilot lights to indicate each parameter status. The microcontroller RS-232 is utilized for the GSM modem communication to upload and download SMS messages that contain information related to the transformer parameters and status.
- GSM Modem block offers high speed wireless connection. It is attached to the microcontroller RS-232 data adapter and can be used as a stand-alone modem. It can be connected to a personal computer, stand alone embedded system or other devices via their serial ports The GSM modem is used as a short message server (SMS) device. It can send and receive messages containing a maximum of 160 characters [8]. In this application, the GSM modem is interfaced with the microcontroller via its RS-232 adapter. The modem receives a message from the microcontroller that contains the transformer information such as location, ID, load currents and temperature. It will then transmit the parameters as an SMS to pre-stored GSM device numbers according to a preset policy. The receiver can be a utility personnel such as maintenance technician, operation engineer or/and authorized utility personnel. Also, it can receive SMS messages from any one of the above mentioned personnel acquiring more information.
- Mobile users and GSM networks: The mobile users are authorized utilities personnel with GSM mobile telephone set with a valid SIM chip. The GSM network is the public mobile phone network that is provided to all users by the mobile service providers.
- The PC-based server is off-the-shelf Pentium 4 with sufficient requirement to handle limited database application.

III. SOFTWARE ARCHITECTURE

Using the microcontroller native language, a software algorithm was developed and implemented to command the system operation. The algorithm starts by initializing the input/output ports data direction flow, set the ADC channels and reset all related memory locations that are going to be used in the operation. Then, it begins to command the system according to the following sequence:

- Rest all variable values,

- Read currents, voltages and temperatures,
- Check for abnormities. If any abnormality exists, send SMS messages using the pre stored mobile numbers i.e. Operation Engineer, technician or any authorized personnel,
- Store values and display readings,
- Repeat the whole process again.

The software algorithm takes about 500 ms to acquire, process, transmit / receiver SMS message do the attached modem, display and update the LCD / LEDs pilot indicators

The required time to sending or receiving SMS to/from the GSM modem to/ from the utility personnel depends on the GSM network speed, number of users and their coverage area. It varies from 2-10 seconds.

The accuracy of the reading relies on the ADC resolutions, current and voltage transformers, signal conditioning circuit gain and offset. The microcontroller ADC resolution is ± ½ least significant bit (LSB). It is about 10 mV on a 5000 mV scale. This error can be adjusted inside the software algorithm. Errors introduced by the temperature sensors, current transformers and voltage transformers are ignored.

Future work is under process to extend the system to utilize the server and a database system. This database system will periodically store all the parameters from the transformers and later this data can be used for useful analysis. Also, error correction, offset and gain adjustment circuits can be added to the signal conditioning circuit to minimize the error and enhance the accuracy.

IV. Implementation And Testing

A study case was conducted on a 1000 kVA transformer (residential load). Load, oil and ambient temperature were monitored for 24 hr summer peak (figure 2).

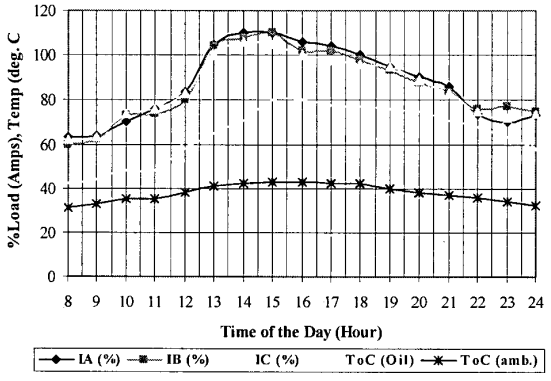

Figure2. Load current and temperature measurement for a peak day.

During the peak hrs (12:30 to 18:00), the unit was serving between 100% - 110% load with oil and ambient temperatures around 80 °C and 43 °C respectively and has influence on the transformer performance accordingly. This normally occurs when the consumer exceeds its contractual load demand. Such loading and temperature status are sent automatically as SMS message to a designated mobile user such as operation engineer. Based on the received SMS message an action will be taken according to the utility policy. For testing purposes, the abnormal current limit was set at 80% load current.

Figure 3 shows two different messages that received by a designated mobile user who has PDA with mobile phone SIM card. The messages are received when the load current became more that 80% for any one of the three lines current. It shows that around 12:10 pm, an SMS message was received as shown in figure 3. Around 4:00pm, the pick current reached 106%. At this point of load, an action must be taking. It is worth mentioning that the line voltages are acquired at the embedded system site and displayed locally and were not included in the SMS message. If it is needed, several code lines can be added to include the line voltages in the SMS message.

Figure 3. Experimental results show two SMS messages

The message takes from 2-10 seconds to be transmitted from the transformer to the mobile device. This delay is dependent on GSM network traffic. In case, the mobile user is outside the coverage area of the GSM network, the SMS message is delivered the moment the user enters the network coverage area. However the time stamp the message is for the present time rather than the instant when the message was sent. This discrepancy can be overcome by putting a time stamp on the message in the embedded system before it is transmitted. This system is currently being extended to include a server module located at a central control center for the utility that can periodically receive and

store transformer parameters information. This data can later be used for different types of analysis.

V. CONCLUSIONS AND FUTURE WORK

A mobile monitoring system for distribution transformer was designed, implemented and tested. The designed system is connected to a distribution transformer and is able to record and send abnormal operating parameters information to a mobile device using a GSM network. The time to receive the SMS messages varies from 2-10 seconds and this is due to the public GSM network traffic. The system hardware was constructed from off-the-shelf components. The experimental results came out as expected. A server module can be added to this system to periodically receive and store transformer parameters information about all the distribution transformers of a particular utility in a database application. This database will be a useful source of information on the utility transformers. The stored data can be analyzed to help the utility in monitoring the operational behavior of their distribution transformers and identify faults before any catastrophic failures thus resulting in significant cost saving as well as improving system reliability.

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