International Journal of Research in Advanced Engineering and Technology
ISSN: 2455-0876; Impact Factor: RJIF 5.44
Received: 08-11-2018; Accepted: 11-12-2018
www.newengineeringjournal.in
Volume 5; Issue 1; January 2019; Page No. 32-40

Design and implementation of a microcontroller-based monitoring system for oil filled distribution transformer

Mamilus A Ahaneku[1*], Ndubueze Chukwunwike[2], Udora N Nwawelu[3]
[1-3] Department of Electronic Engineering, University of Nigeria, Nsukka, Nigeria

Abstract
The maintenance of a distribution transformer to ensure durability requires close monitoring and control. In the time past such transformers were allowed to operate until breakdown occurs. This usually results to long period of down time due to cost implications. This project is aim at designing a model that could be used to monitor the important parameters of the system such as oil level, voltage, current, and temperature levels. Sequel to this, control actions necessary to prevent unexpected breakdown and improve the reliability of power substations are carried out. This project also implements a sensitive data acquisition system by exploiting the versatile capabilities of the PIC microcontroller and by employing some other engineering techniques such as the hardware design and software development. Test results show that the system performs well with high level of system sensitivity and accuracy.
p

Keywords: transformer, distribution, voltage, control

1. Introduction

Maintaining power distribution/transmission equipment has always been an inevitable and critical task for engineers and other power management personnel. Owing to the continuous flow of power through the devices, they are prone to overheating, burning, explosions, intermittent breakdown and other forms of damage and malfunctions. In power systems, distribution transformer is substation electrical equipment which gives out power to the low voltage users directly. It provides the final voltage transformation in the electric power distribution system, stepping down the high voltage power got from the transmission end to a level (usually 220V) and distributes this domestically usable voltage power to the customers in the area. Distribution transformers normally have ratings less than 200KVA. However, some national standards can describe units up to 5000KVA as distribution transformers.

Emphatically, the operation conditions of distribution transformers constitute important components of the entire distribution power network operations in locations where they are found.

Preserving the health and reliability of power substations has really been a concern for many years. For this reason, maintenance crews would periodically take transformers circuit breakers offline, in order to assess whether the equipment is operating normally or not. With this method, there are still catastrophic failures, including the performance of many unneeded maintenance activities. With a growing need for lower cost and more efficient diagnostic tools, the advent of online monitoring and artificial intelligence analysis techniques have been applied to the electrical power substations. Operation of distribution transformers under rated conditions (as specified in their nameplates) guarantees their long life [1]. However, their life is significantly reduced if they are subjected to overloading, resulting in unexpected failures and loss of supply to a large number of customers.

The application of the monitoring system comes in handy when one forgets to do simple things such as turning devices ON or OFF. One can, however, get an alarm prompt and circuit breaking mechanism which secures his equipment. This development ultimately saves a lot of time for everyone and eases daily life existence. This monitoring system proves to be a powerful and flexible tool that offers service at any time within the ambits of the technologies being applied. The monitoring system also is to have sensors which detect changes in the different parameters of the transformer. The sensors are current sensors, voltage sensors, temperature sensor and oil level sensor. They receive regular information about the parameters of the transformer such as current, voltage, temperature and oil levels and convert them to analogue signals. Thereafter they transfer these analogue signals to a Peripheral Interface Controller (PIC) microcontroller which contains an Analog-to-Digital Converter (ADC) which helps it to decode the information. The sensors are connected to the microcontroller. The microcontroller is to be programmed to scan the transformer continuously and update its parameters at regular and specific intervals. The scanned values of the parameters are then processed and stored in the system memory. This is then displayed by the LCD display which is connected to the microcontroller and Power Supply Unit. If this monitoring system is connected to the oil filled distribution transformer, in the event of any anomaly, the microcontroller will detect it and trigger the necessary relay, contactor and alarm operations. Subsequent disconnections will prevent any catastrophic damage to the equipment.

2. Related Works

Monitoring system which involves neuro-fuzzy technique was executed in [2]. The work presents an advanced predictive maintenance and diagnostic system that can be used to monitor the health of the transformer and other substation equipment. The authors designed a portable online diagnostic module capable of collecting information about current, temperature, and vibration from non invasive sensors. This information is sent to the substation computer for storage. Also, the system has the ability to remotely access the data for analysis and health assessment.

A low cost system for monitoring health condition of remotely located distribution transformers using GSM technology was executed in [3]. With the GSM module incorporated into the system, it could send the data which was displayed by the Liquid Crystal Display (LCD) to a GSM phone. On receiving data about the state of the transformer on real time, reliability of the distribution transformers is improved. An embedded based hardware design is developed to acquire data from electrical sensing system. It consisted of a sensing system, signal conditioning electronic circuits, advanced embedded hardware for middle level computing, a computer network for further transmission of data to various places. The performance of the prototype model was tested for monitoring various parameters like transformer overload, voltage fluctuations, over temperature, oil quality and level.

Going by the methods suggested by the related works, we observed that the involvement of the neuro fuzzy network and technique in the monitoring system resulted to inaccurate information and slow response to the changes in the parameters of the transformer. Also, it increases the complexity of the system design. To address these shortcomings, we propose a simple and efficient microcontroller based monitoring system for oil filled distribution transformer. The system is simple and efficient owing to the fact that; it does not include any GSM technology and hence does not possess the irregularities and inconsistencies of the mobile data transmissions, also the non-involvement of the neuro-fuzzy network and technique creates a simple monitoring system which has an accurate and fast response to the changes in the parameters of the transformer.

3. Materials and Methods

The material used to achieve this design are; microcontroller, ultrasonic sensor, temperature sensor, current transformer, potential transformer, MikroC programming language. These materials are discussed below;

PIC16F77A Microcontroller: The PIC16F77A microcontroller is a well-known microchip. It has all the attributes of modern microcontrollers. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as the control of different processes in industry, machine control devices, measurement of different values and so on.

Ultrasonic Sensor: This is used in oil level detection. Ultrasonic sensors work on a principle similar to that of radar or sonar, which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. This sensor operates with a piezoelectric transducer as the sound emitter and receiver. The ultrasonic transducer is embedded, watertight, into the sensor housing, in polyurethane foam. The transducer transmits a packet of sonic pulses and converts the echo pulse into a voltage. The integrated controller computes the distance from the echo time and the velocity of sound. The transmitted pulse duration and the decay time of the sonic transducer result in an unusable area in which the ultrasonic sensor cannot detect an object [4].

Temperature Sensor: LM 35 is used as a temperature sensor. The LM 35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature [5]. The LM 35 has an advantage over linear temperature sensors calibrated in ˚Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

Current Transformer: The use of current transformer as current sensor reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter.

Potential transformer as a voltage sensor: Potential transformer **or** voltage transformer finds its use in an electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays. This property of the potential transformer makes it usable as a voltage sensor in project like this.

MikroC programming language: MikroC is a programing language which can be used to effectively programme and control the operations of the PIC microcontroller. The programming language has a powerful and efficient compiler which is known as the MikroC PRO for PIC. This compiler is used as an Integrated Development Environment (IDE) on which the MikroC programme is written, tested and run. And from it, it can be stored and "burned" unto the PIC microcontroller. Then, the microcontroller will start to behave and respond according to the dictates of the programmed code. The MikroC is a version of C programming language. Figure 1 shows a capture of the Integrated Development Environment (IDE) of the MikroC PRO for PIC compiler.

4. Design and Implementation

4.1 System Specifications

Table 1: Design Parameters

Parameters	Rating
Input Voltage	220V to 240V
Output Voltage	140V to 260V
Frequency	60Hz
Input Current	2A
Output Current	2A
Relay	12 Volt, 30 Ampere
Centre-tap Transformer	18V, 500mA
Two Transformers	12V, 500mA
Buzzer	3 – 24V

4.2 System Design and Development

This section involves the actual hardware design of the monitoring system. The different units of the system are analyzed in this section, according to the mode of design and prioritization. These units are; the power supply unit, the alarm unit, the output control unit, the microcontroller unit, and the liquid crystal display.

Power Supply Unit: This unit supplies power to each component in the equipment. Power supply unit contains a step down transformer which steps down the 220V (or 230V in some locations) distributed supply from the mains to

12V.

Alarm Unit: Alarm unit is activated when the microcontroller senses an abnormal condition or value in the parameters of the transformer. The actual intention for the inclusion of this unit in the design is to notify persons of any possible anomaly through sound [6].

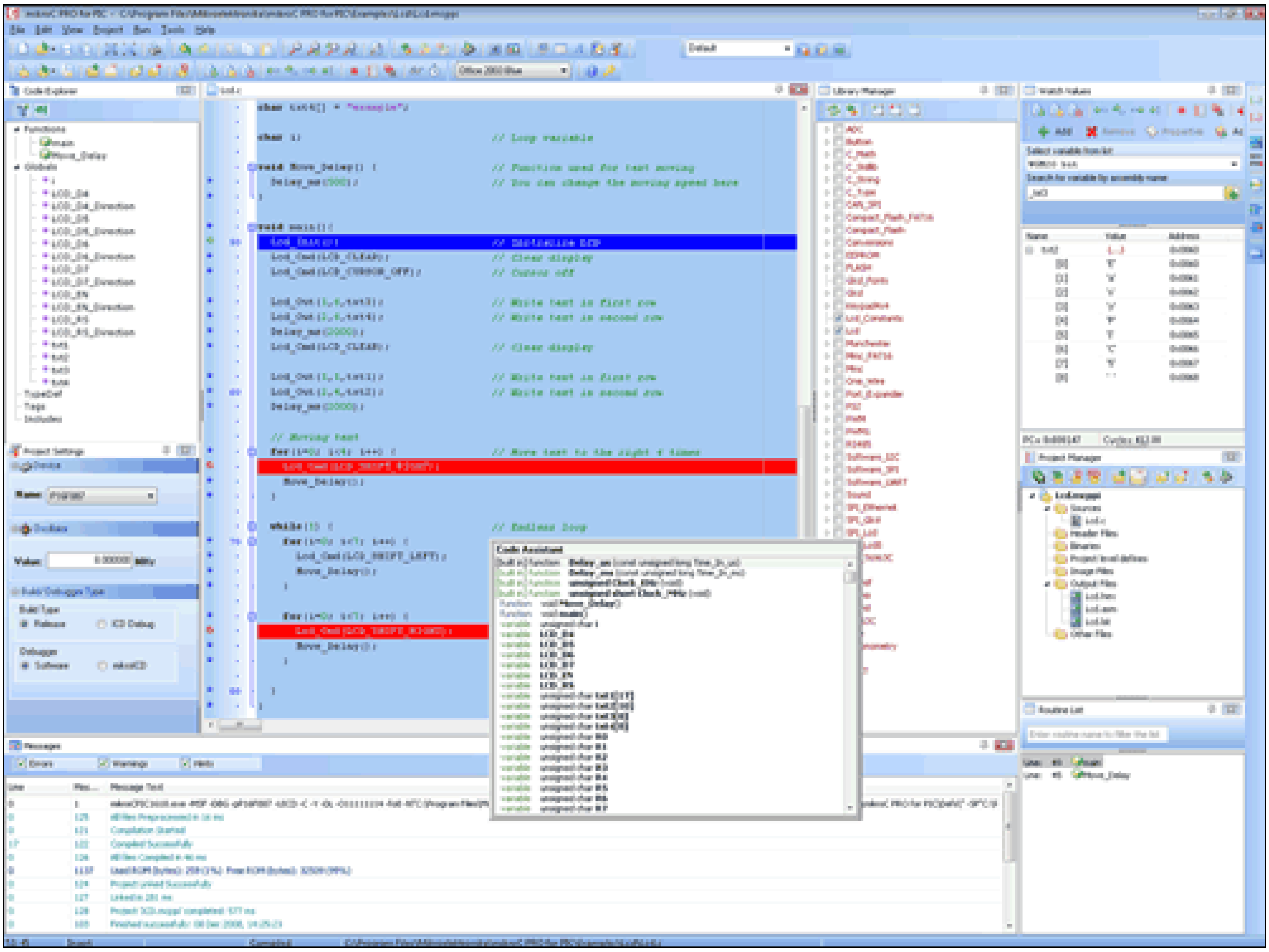

Fig 1: The IDE of the MikroC PRO for PIC Compiler.

Output Control Unit: This unit is in charge of keeping both the transformer and the loads safe. It does this by switching off connections appropriately when there is an over voltage, over current or any other anomaly. It usually contains relays and contactors.

Microcontroller Unit: The microcontroller unit is the major control unit of the monitoring system. It is the unit which integrates the coordination and interaction of both the software and the hardware components of the system. It is the brain of the monitoring system. Hence, it functions to enable the monitoring capabilities of the system. The PIC microcontroller used for this project has been programmed by a software code written by the MikroC language, with the MikroC PRO for PIC compiler. The PIC microcontroller is programmed by using the PIC hardware programmer. The programmer used for the program burning of this project is the "The Universal Programmer". A computer system is used together with this programmer to input the MikroC language written codes into the hardware PIC microcontroller. This PIC chip is fixed into the programmer and the codes are copied (burned) unto it (the PIC microcontroller) through the computer system which contains the written codes. When the copying is concluded, the PIC microcontroller is now brought out and connected to the circuit of the monitoring system. The microcontroller then starts behaving in accordance with the commands of the program codes "burned" unto it. It receives the analog data from the sensors and sends out appropriate output information to the alarm unit, output control unit and the display unit (LCD). The PIC microcontroller used for this project has three types of memory ROM, RAM and EEPROM.

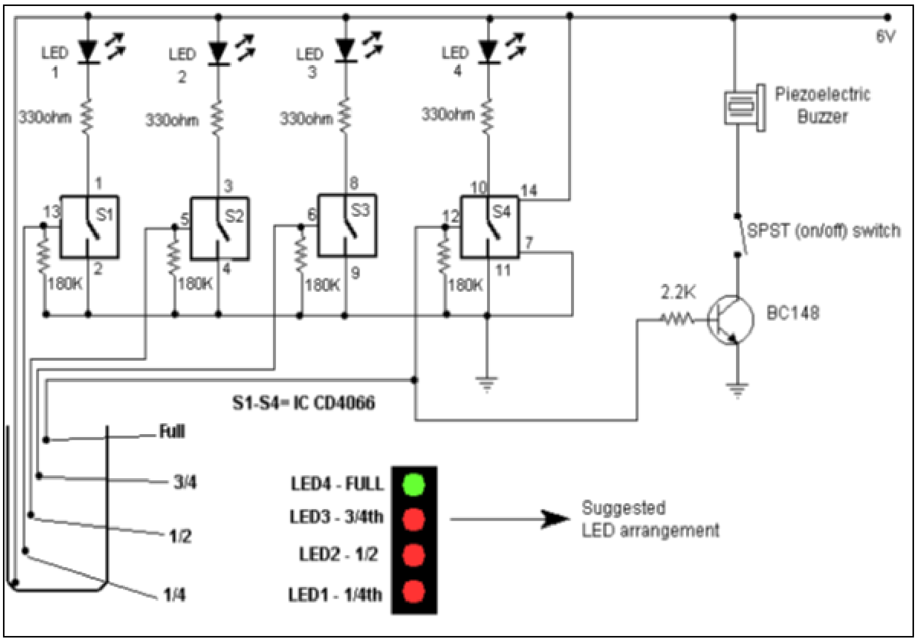

Fig 2: Indicator Alarm System

4.3 MikroC Programs and Platforms

IDE for MikroC PRO for PIC: The Project Manager Window enables one to handle code processing. The code explorer window enables one to easily locate functions and procedures within long programs. For example, if one look for a function used in the program, just double click its name in this window, and the cursor will be automatically positioned at an appropriate point in the program. In order to enable the compiler to operate successfully, it is necessary to provide it with basic information on the microcontroller in use as well as with the information on what is expected from it after the process of compilation. Figure 3 is a capture of the IDE of the MikroC PRO for PIC Compiler. This capture highlights the segments of the IDE [7].

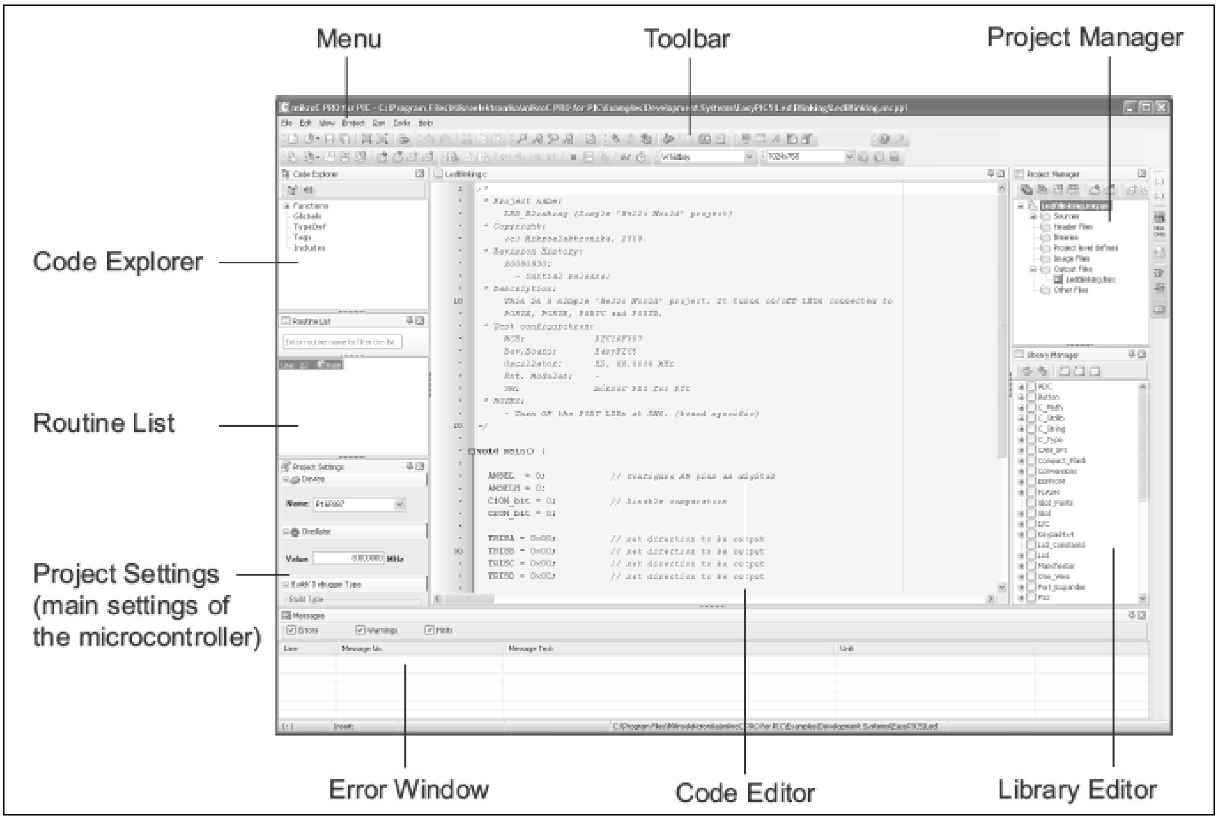

Fig 3: MikroC PRO for PIC IDE with Segments Labelings

MikroICD (In-Circuit Debugger): MikroC PRO for PIC compiler has an efficient debugging feature which is usually used to program the PIC microcontroller properly. This debugger is known as MikroICD. MikroICD is a highly effective tool for real time debugging on hardware level. ICD debugger enables one to execute a MikroC PRO for PIC program on a host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM as the program is running [8]. Two major steps of implementing ICD are enumerated;

Step 1
When operating the appropriate hardware and software for using MikroICD, upon completion of writing the program, ICD Debug build type is chosen. In the MikroC PRO for PIC compiler used for this project, which is the version 6.4.0 build, the "Project Settings" option is under "View" header in the Main Menu of the MikroC PRO for PIC compiler Integrated Development Environment (IDE).

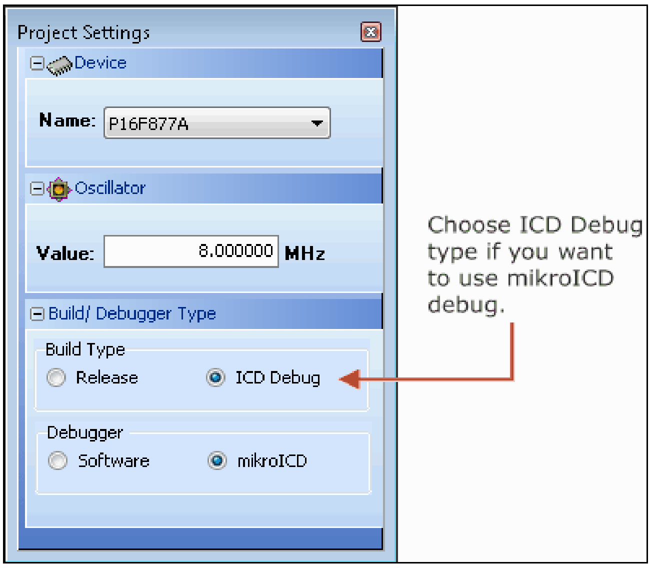

Fig 4: ICD Debug and MikroI CD Illustration

Step 2
MikroICD is run by selecting Run › Debug from the drop down menu, or by clicking Debug icon. Starting the Debugger makes more options available: Step Into, Step Over, Run to Cursor and so on. Line that is to be executed is color highlighted (blue by default). There is also notification about program execution and it can be found on "Watch Window" (yellow status bar). These are shown in Figure 5.

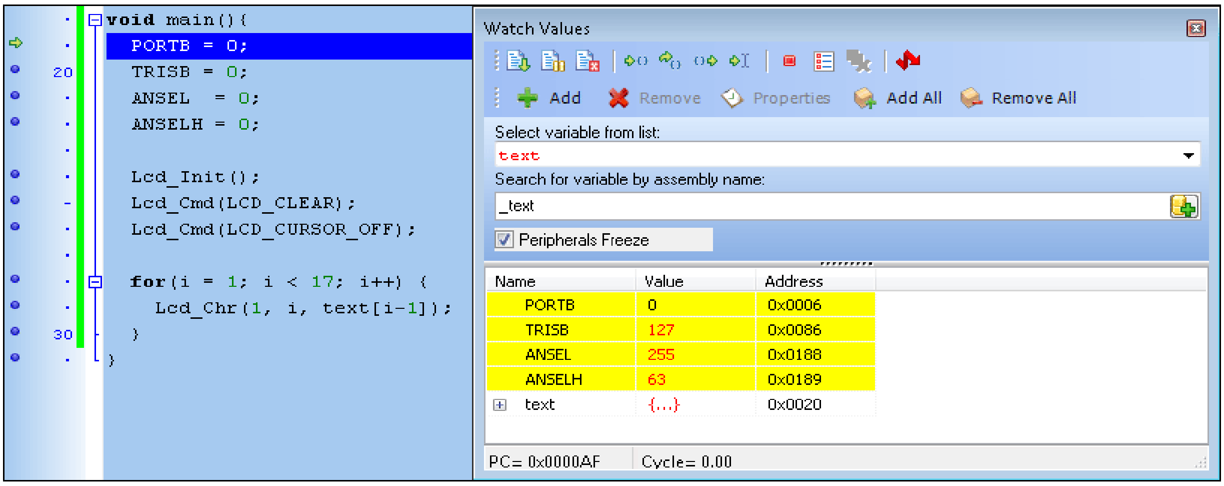

Fig 5: MikroC PRO MikroICD Watch Window

4.3.1 MikroICD Debugger Example

Here is a step by step MikroICD Debugger situation which is similar to the one encountered in the execution of this project.

Step 1
A program on how MikroICD works is written below.

```
// LCD module connections
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;
sbit LCD_RS_Direction at TRISB4_bit;
sbit LCD_EN_Direction at TRISB5_bit;
sbit LCD_D4_Direction at TRISB0_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD module connections
char text [17] = "mikro Elektronika";
char i;
void main (){
PORTB = 0;
TRISB = 0;
```

```
ANSEL = 0;
ANSELH = 0;
Lcd_Init();
Lcd_Cmd(_LCD_CLEAR);
Lcd_Cmd(_LCD_CURSOR_OFF);
for(i = 1; i < 17; i++) {
Lcd_Chr(1, i, text[i-1]);}}
```

Step 2

After successful compilation and PIC programming, F9 is pressed. This starts the Mikro ICD. After MikroI CD initialization, the blue active line should appear:

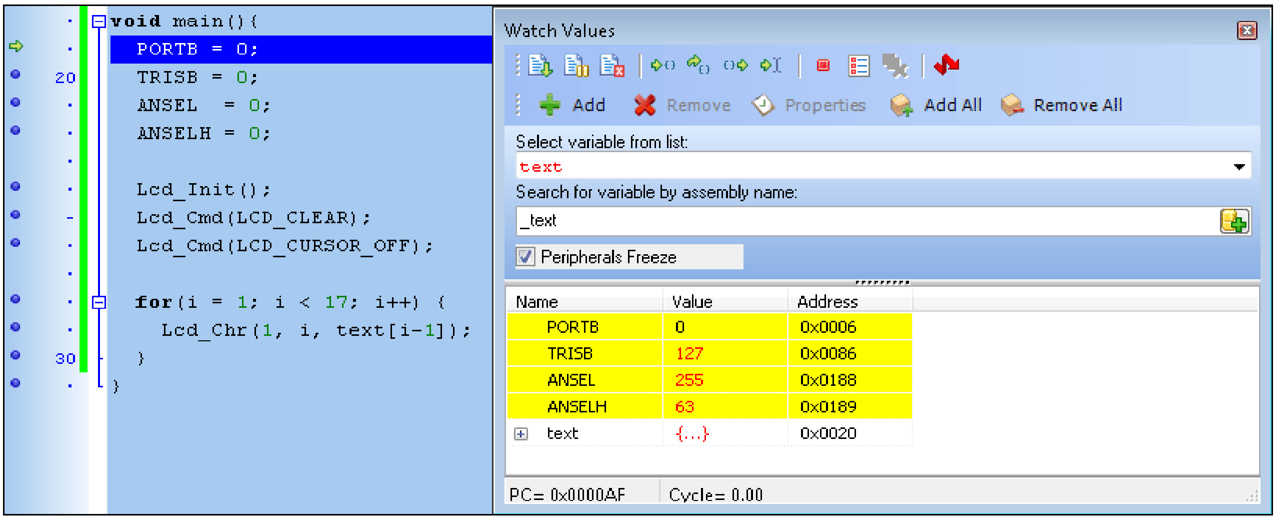

Fig 6: MikroI CD Initialization Window

Step 3

The debugging of the program is done line by line. If F8 is pressed, line by line execution of the code resumes. It is recommended that user does not use Step into [F7] and Step Over [F8] over Delays routines and routines containing delays. Instead use Run to cursor [F4] and Breakpoints functions. All changes are read from PIC and loaded into the Watch Window. Note that PORTB, TRISB, ANSEL and ANSELH changed their values.

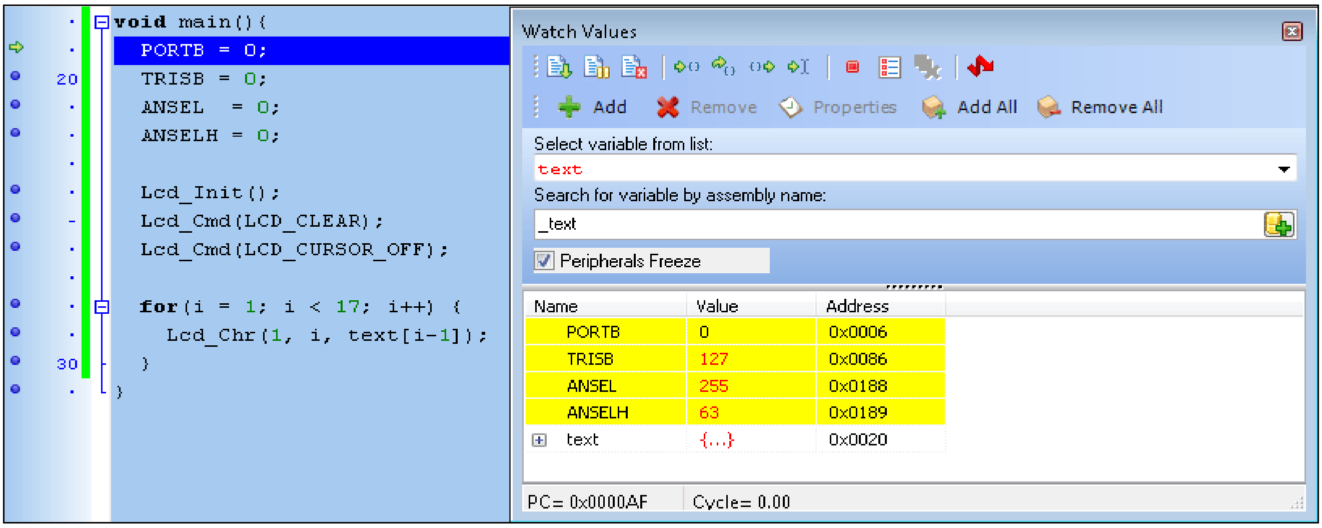

Fig 7: Line by Line Program Debugging Window

Step 4

Step into [F7] and Step Over [F8] are MikroICD debugger functions that are used in a stepping mode. There is also real time mode supported by MikroICD. Functions that are used in real time mode are Run/Pause Debugger [F6] and Run to cursor [F4]. Pressing F4 goes to the line selected by the user. The users just have to select line with cursor and press F4, and the code will be executed until the selected line is reached.

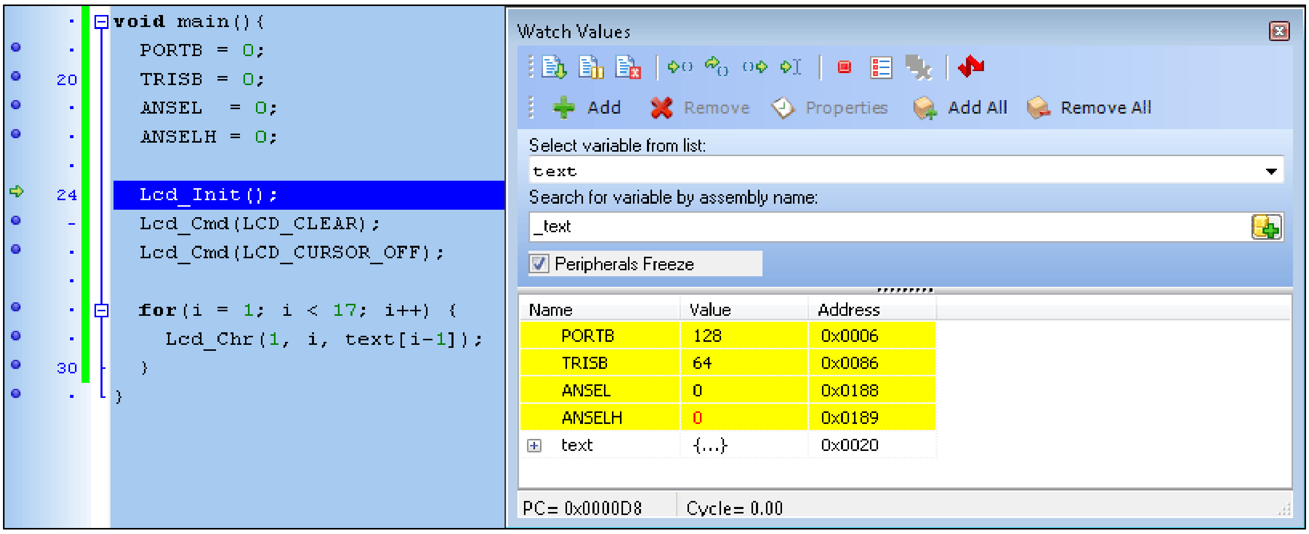

Fig 8: Real-Time Mode Window

Step 5

Run Debugger [F6] and Toggle Breakpoints [F5] are MikroICD debugger functions that are used in real time mode. Pressing F5 marks line selected by the user for the breakpoint. F6 executes code until a breakpoint is reached. After reaching the breakpoint, Debugger halts. At this point, breakpoints for writing "MikroElektronika" on Lcd char by char are used. Breakpoint is set on Lcd Chr, and the program will stop every time this function is reached. After reaching the breakpoint, F6 must be pressed again so as to continue program execution.

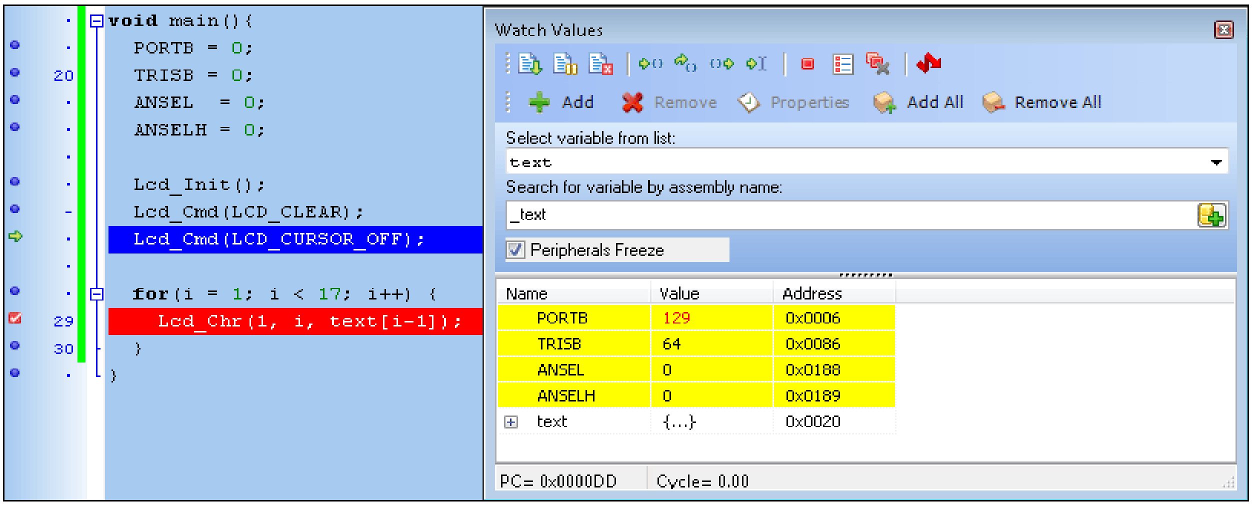

Fig 9: Breakpoint Debugger Function Window

Breakpoints have been separated into two groups. There are hardware and software breakpoints. Hardware breakpoints are placed in PIC and they provide fastest debug. A number of hardware breakpoints are limited (1 for P16 and 1 or 3 for P18). If all hardware breakpoints are used, next breakpoints that will be used are software breakpoint. Those breakpoints are placed inside MikroICD, and they simulate hardware breakpoints. Software breakpoints are much slower than hardware breakpoints. The differences between hardware and software differences are not visible in MikroICD software, but their different timings are quite notable. Therefore, it is important to know that there are two types of breakpoints. The complete schematic diagram is in appendix A.

5. Testing and Results

The normal working of the entire circuit was tested using a multimeter. It was used to make the necessary measurements on the circuit boards, and to make normal continuity checks on the appropriate parts of the monitoring system. The multimeter was also used to confirm the accurate working conditions of the individual components of the system. A check was also made to ensure that the soldiering and all the circuit implementations are done well. Tests were also made to ensure that there were no bridging or erratic errors in the circuitry. Moreover, checks were also made to ensure that all the interfaced subsystems/modules were working and inter relating properly. This is to confirm that the system make up works perfectly as a single system. After all these, the system unit was connected to a 220V power source for the final functional testing.

At the powering of the system, it was found that the monitoring system was functioning appropriately. All the different subsystems of the system received power according to the design that was envisaged. The LCD displayed the appropriate and corresponding values of the parameters of the test transformer at each of the tests conducted. At all points, the numerical values of the four parameters (voltage, current, oil level and the temperature) of the transformer were notified to all observers on the LCD. The buzzer sounded whenever the values of the parameters reached all the critical and abnormal values of each of the four parameters, according to the program stored in the microcontroller. Also, the output control unit made the necessary disconnections at such points.

Test 1: The voltage values of the test transformer are varied by turning the light dimmer towards the positive direction until it reaches 260V. This is tabulated in table 1.

Table 1: Variation of the voltage values of the test transformer by turning the light dimmer towards the positive directionupto 260V.

Transformer Parameters	Liquid crystal display output	Buzzer reaction
Voltage	"High Voltage"	Buzzer sounds
Current	Normal current value	No buzzer sound
Temperature	Normal temperature value	No buzzer sound
Oil level	Normal oil level value	No buzzer sound

Test 2: The voltage values of the test transformer are varied by turning the light dimmer towards the negative direction until it reaches 140V. This is tabulated in table 2.

Table 1: Variation of the voltage values by turning the light dimmer towards the negative direction up to 140V.

Transformer parameters	Liquid crystal display output	Buzzer reaction
Voltage	"Low Voltage"	Buzzer sounds
Current	Normal current value	No buzzer sound
Temperature	Normal temperature value	No buzzer sound
Oil level	Normal oil level value	No buzzer sound

Test 3: Variation of the temperature values by applying heat to the LM35 sensor until it reaches 36º C. Actually, the critical value for a distribution transformer is 65º C. But the temperature below the critical level is chosen because it is difficult to raise the temperature of the transformer high. This is tabulated in table 3.

Table 3: Variation of the temperature values by applying heat to the LM35 sensor until it reaches 36º C.

Transformer Parameters	Liquid Crystal Display Output	Buzzer Reaction
Voltage	Normal voltage value	No buzzer sound
Current	Normal current value	No buzzer sound
Temperature	"High Temperature"	Buzzer sounds
Oil level	Normal oil level value	No buzzer sound

Test 4: Variation of the current values by turning the light dimmer towards the negative direction and (increasing the load by adding more bulbs) until it reaches 2A.

Table 4: The current values variation by turning the light dimmer towards the negative direction and until it reaches 2A.

Transformer Parameters	Liquid Crystal Display Output	Buzzer Reaction
Voltage	Normal voltage value	No buzzer sound
Current	"high Current"	Buzzer sounds
Temperature	Normal temperature value	No buzzer sound
Oil level	Normal oil level value	No buzzer sound

Test 5: Variation of the oil level values by draining the liquid level to the 40% level.

Table 5: The oil level values variation by draining the liquid level to the 40% level

Transformer Parameters	Liquid crystal display output	Buzzer Reaction
Voltage	Normal voltage value	No buzzer sound
Current	Normal current value	No buzzer sound
Temperature	Normal temperature value	No buzzer sound
Oil level	"Low Oil Level"	Buzzer sounds

All these tests confirm that the monitoring system is functioning well.

5. Conclusions

Owing to the deplorable state of power generation, transmission and distribution in Nigeria presently, there are regular incidents of transformer breakdown. These are largely as a result of overloading and overheating of these transformers. Low oil level in transformers causes the overheating of transformers, even if they are not overloaded. The oil is very important as a coolant, insulator and a suppressor of corona and arcing (sparking). The aim of this design is to come up with an efficient power and distribution transformers monitoring systems. These systems are to have very sharp, data acquisition and sensing capabilities, so as to prevent damage and breakdown of the power equipment. This will be a major means of the improved revenue generation as good amount of money is saved from the repairs of damaged transformers. It also ensures constant power supply in Nigeria, which will have a positive spillover effect of improving the economy of Nigeria remarkably.

Proposed microcontroller-based monitoring system for oil filled distribution transformer can be further improve by (i) monitoring and regulation of some other parameters of the transformer such as; oil temperature, winding temperature, humidity and oil viscosity level. These can advance the health and longevity of the transformers and other such devices. (ii)

Inclusion of some extra security measures in the monitoring system implementation. This is to reduce the event of theft and vandalization when installed in an unsecure environment. (iii) Incorporating a server module for receiving and storing transformer parameters. This information can be stored using a database application which is capable of collecting the information of several transformers. These data will also help in making a helpful forecast about the operations of the monitored devices. (iv) SIM900 modules can also be included in the monitoring system so as to ensure more prompt monitoring and remote parameter condition notifications. Hence, mobile phones and other compatible electronic devices can receive the transformer information.

6. References

1. Sharma A. GSM based Distribution Transformer Monitoring System. Department of Electrical Engineering, National Institute of Technology, Rourkela, India, 2013.
2. Shoureshi R, Norick T, Swartzendrube R. Intelligent Transformer Monitoring System Utilizing Neuro-Fuzzy Technique Approach. Power Systems Engineering Research Center (PSERC) Publication, 2004.

3. Vadirajacharya K, Kharche K, Kulakarni A, Landage H. Transformer Health Condition Monitoring through GSM Technology. International Journal of Scientific and Engineering Research, 2012.
4. Pepperl F. Ultrasonic Sensors [Published Book]. Steven Engineering Publication, 2005.
5. LM35 Datasheets [Published Manual]. National Semiconductor Publication, 2000.
6. Ahmed M. Development of a Simple Sound Activated Burglar Alarm System [Published Project Report], Leonardo Journal of Sciences Publication, 2006.
7. Verle M. PIC Microcontrollers Programming in C [Published Book]. Mikro Elektronika Publication, 2009.
8. Mikro Elektronika, Mikro C PRO for PIC [Published Book]. Mikro Elektronika Publication, 2009.