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The GSM Based Monitoring of Distribution Transformer

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Abstract- The purpose of the system design paper is to solve complex and eradicate the problems encountered using the local protection techniques such as fuse, circuit breakers etc. The research is based on microcontroller transformer monitoring with real-time data logging capabilities. This monitoring is focused on the transformer parameters feed into the ADC of the microcontroller and monitoring the transformer voltage, current and temperature through via an LCD. The voltage transformer will be connected across a variable AC input source using an autotransformer which can be varied from 0-259VAC. The output of the transformer (secondary) will be connected to electric bulbs which will serve as load. The load current will be monitored by connecting a current sensor in series between the load and the secondary side of the transformer. The transformer voltage will be monitored through rectifying a step down 230-12VAC transformer to a pure 5VDC and then feed to the microcontroller ADC pin for voltage monitoring. The input of the step down transformer will be connected to autotransformer and the output will be perfectly rectified to a pure 5VAC. Similarly, the microcontroller monitor's the load current and temperature of transformer and displays the values on LCD. As the load current exceeds the rated current rating of the transformer, the temperature of the secondary winding rises, therefore the microcontroller will send an SMS through the GSM modem to the control room and to the Technical Service Manager, informing them of the parameters.

Keywords- *Microcontroller, LCD, ADC, GSM Modem*

I. INTRODUCTION

In recent years, increased emphasis has been placed on power reliability and economy. In particular, major changes in the utility industry have caused increased interest in more economical and reliable methods to generate, transmit and distribute electric power. In this regard, monitoring the health and operational posterity of equipments constitutes the system is critical to ensure that the supply of power can meet the demand.

Distribution transformer is a critical equipment in power system operation which distributes power to the low-voltage users directly. Operation of distribution transformer under rated condition (as per specification in thier nameplate) guarantees their long life. Howerver, their life span and reliability is significantly reduced if they are subjected to overloading, resulting in unexpected failures and loss of supply to a large number of customers thus affecting system reliability. Overloading and ineffective cooling of transformers are the major causes of failure in distribution transformers. Therefore, monitoring of key parameters are necessary for evaluating the performance of the distribution transformer and also helpful to avoid or reduce disruption due to sudden unexpected failures.

Monitoring in the context of this research entails remote collection of data and include sensor development, measurement techniques for real-time application.

II. SYSTEM DESIGN

The proposed system is based on microcontroller (Arduino) that monitors the voltage, current, and temperature of a distribution transformer. The device is fixed on the secondary of the distribution transformer and the monitored output will be display on an LCD. The monitored output values are compared with the rated values of the transformer and the microcontroller is programmed in such a way that if the monitored values, exceeds a certain set value then the microcontroller sends an SMS (short message service) to an authorized personnel through the GSM modem. Also at the time fault occurs it shows a warning message on the monitoring station. The microcontroller continuously scans the transformer and updates the parameters in the monitoring station.

III. RESEARCH DESIGN METHDOLOGY

Following scheme depicts the sequence of methodologies followed in the monitoring of distribution transformer via GSM technology.

- First sensors which are installed at the transformer site sense the various parameters of transformers and convert into analog signal to be processed in signal conditioning circuits
- Next the SCC consisting of op amps and resistors manipulates the analog signal to a compatible value so they can be read by the embedded system.
- Next the signal is passed through microcontroller. The ADC (the Arduino has an ADC embedded in it) is used to read the parameters, built-in EEPROM 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 GSM modem is interfaced with the microcontroller through RS 232 adapter by which it uploads and downloads SMS messages that contain information related to the transformer parameters and status.
- This GSM modem then sends this SMS to mobile users containing information about parameters value of the distribution transformers.

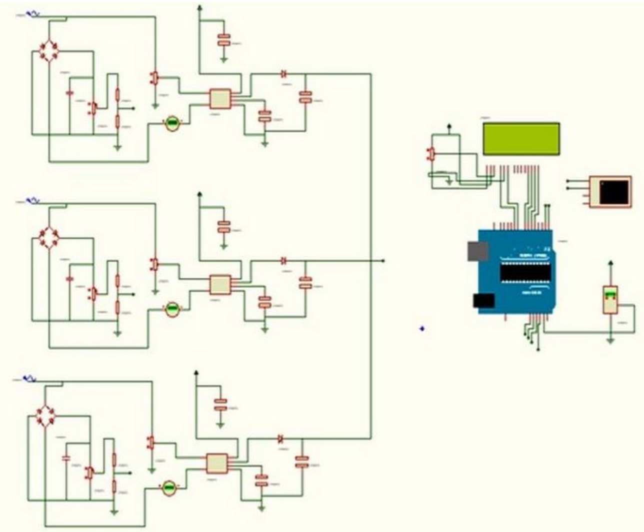

Figure 1. Circuit Diagram of the Model

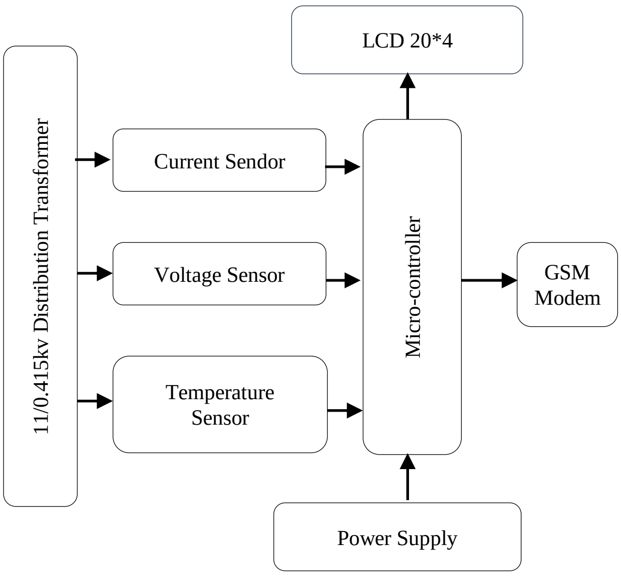

Figure 2. Block diagram of a three phase transformer monitoring system

TABLE I. LIST OF PARAMETERS AND THEIR SENSORS.

S/N	Parameters	Sensors
1	Load current	ACS712
2	Phase voltage	potentiometer
3	Oil temperature	LM32

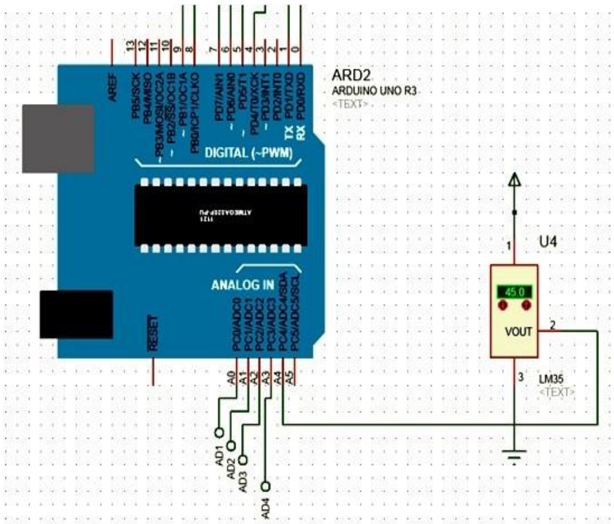

Figure 3. Temperature Sensor interface with arduino

A. *Working Principle Of Acs712 Sensor*

ACS712-30A is a current sensor. When connected to a voltage source, a load must be placed in series with it to enable current flow. It is this current that the sensor detects, and outputs voltage based on Hall Effect. For a DC supply, the output voltage is proportional to the input current; this is however not the same for an AC supply, as used in this project. For an AC supply, some re-calibration must be made seeing that the amplitude of an AC supply is not constant. The input voltage is gotten as a product of the input current and the load resistance causing the current flow. The microcontroller computes the input current from the Hall voltage, sensor supply voltage, and the sensitivity.

The sensor supply voltage (Vcc) is usually 5V and at no supply, the sensor gives a default output of 2.5V; thus the microcontroller outputting 0A for no current.

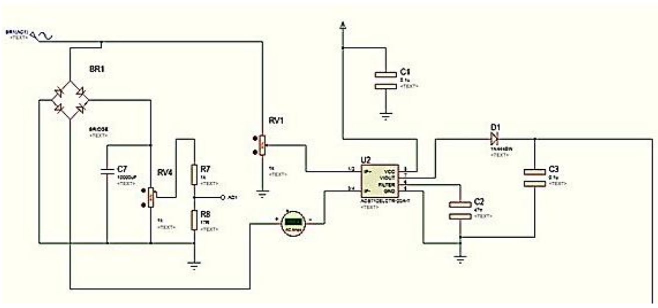

Figure 4. Current Sensing Circuit

B. *MICROCONTROLLER UNIT*

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as pulse width modulation, PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an In-Circuit System Programmer header, and a reset button as shown in fig 3.5a. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega328 programmed as a USB-to-serial converter. “Uno" means "One" in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions.

The technical Specifications are:

i. Microcontroller ATmega328
ii. Operating Voltage 5V
iii. Supply Voltage (recommended) 7-12V
iv. Maximum supply voltage (not recommended) 20V
v. Digital I/O Pins 14 (of which 6 provide PWM output
vi. Analog Input Pins 6
vii. DC Current per I/O Pin 40mA
viii. DC Current for 3.3V Pin 50mA
ix. Flash Memory 32 KB (ATmega328) of which 0.5 KB used by boot loader
x. SRAM 2 KB (ATmega328)
xi. EEPROM 1 KB (ATmega328)
xii. Clock Speed 16 MHz

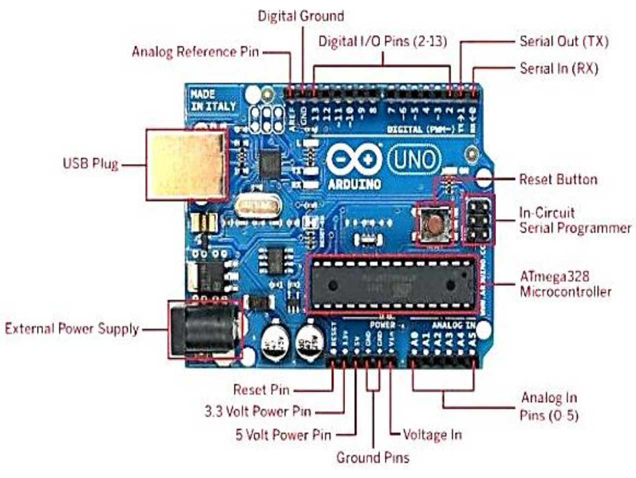

Figure 5. Arduino Uno board

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the Ground and Voltage-in (+v) pin headers of the Power connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

C. *ATmega328 Microcontroller Architecture*

The microcontroller is a low-power CMOS (Complementary Metal Oxide Semiconductor) 8-bit microcontroller based on the AVR. The powerful execution of instructions in a single clock cycle leads to the achievement of 1 MIPS per MHz throughputs allowing the designer to optimize power consumption versus processing speed.

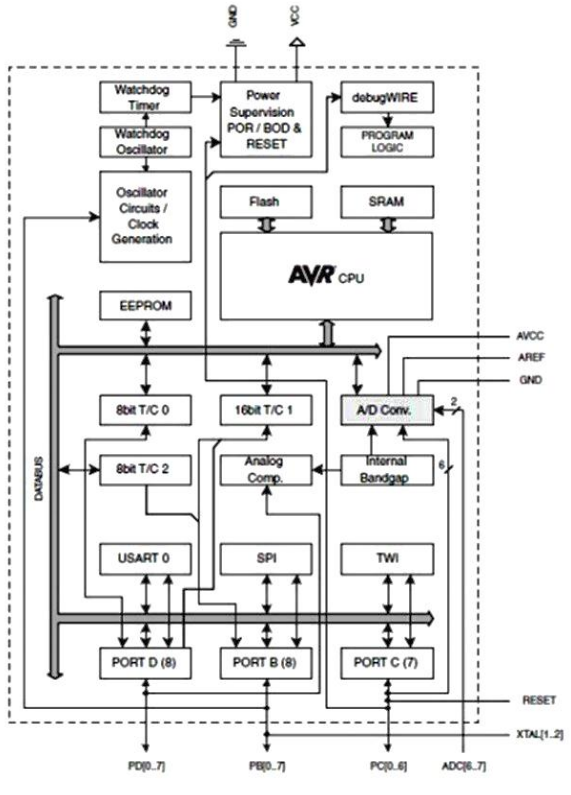

Figure 6. ATmega328 Microcontroller Architecture Reprinted from Datasheet of ATMega328

The internal architecture of the microcontroller is as shown above. The central processing unit (CPU) is the brain of the microcontroller which controls the execution of the program. The Microcontroller unit consists of 4K/8K bytes of in-system programmable flash with read-while-write capabilities, 256/412/1K bytes EEPROM along with the 512/1K/2K bytes of SRAM. Along with this, the Microcontroller unit consists of many other features:

23 general purpose I/O lines and 32 general purpose working registers;

3flexible timer/counters with compare modes, internal and external interrupts and a serial programmable USART; A byte-oriented 2-wire serial interface; an SPI serial port; a 6-channel 10-bit Analog to Digital Converter (8 channels in TQFP and QFN/MLF packages), a programmable watchdog timer with an internal oscillator and 5 software-selectable power saving modes. The five, software selectable, power saving modes are idle mode, Power-down mode, Power-save mode, ADC Noise Reduction mode and the Standby mode, the CPU is the brain of the microcontroller which controls the execution of the program. Therefore the CPU is able to access the memories, perform calculations, control peripherals and handle interrupts. The Arduino uses the Harvard architecture – with separate memories and buses for program and data to maximize the performance as well as the parallelism. The principle of execution of instructions in the program memory is the single-level pipelining. The concept of pre-fetching the next instruction while executing one instruction enables the instructions to be executed in every clock cycle and the program memory is in the System Reprogrammable Flash memory.

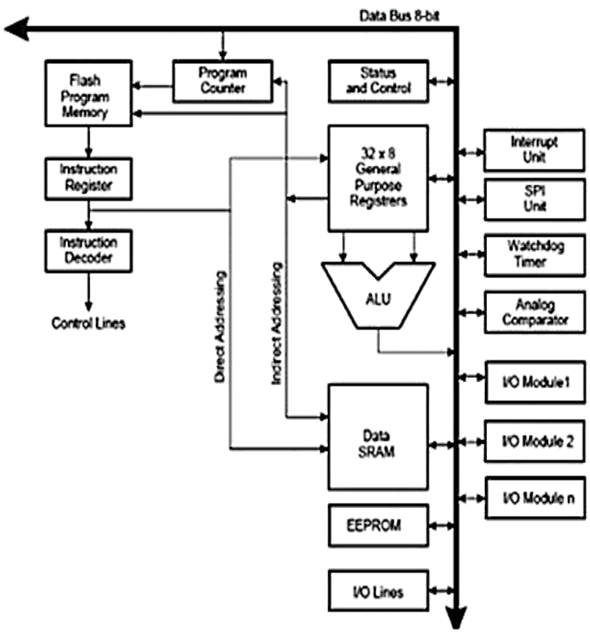

Figure 7. Block diagram of the AVR CPU Core architecture

The block diagram of AVR CPU Core architecture is shown in fig3.13 above. The fast-access Register File contains 32 x 8 bit general-purpose working registers with a single cycle access time which results in a single-cycle ALU operation. The arithmetic and logical operations between the registers or between the constant and a register are supported by the ALU. The status register is updated to reflect information about the result of the operation after an arithmetic operation. The boot program section and the application program section are the two main sections of the program flash memory. Stack stores the return address of the program counter during the interrupts and subroutine calls which is allocated in the general data SRAM. The size of the stack is limited by the total size and usage of the SRAM. The data SRAM is accessible through five different addressing modes supported in the AVR architecture while the stack pointer is read/write accessible in the I/O space. The memory spaces in the AVR architecture are all linear and regular memory maps.

D. System Programming Language

Having designed and built the hardware, the Arduino chip is as good as nothing if there is no program to drive the microcontroller. The software development is done using embedded C programming platform. The choice of embedded C programming language for conditional programming structure as used in the development of the system intelligence, is because it is a high level language, easy to use and understand. The codes were written, compiled and executed in Arduino embedded C IDE environment (sketch) as shown in fig8.

Figure 8. Arduino embedded C IDE environment (sketch)

E. Liquid Crystal Display (LCD)

LCD (Liquid Crystal Display) is an electronic display system. A 20x4 LCD display is a very basic system and commonly used in various devices and circuits. LCD's are preferred over seven segments and other multi segment LEDs. The advantages of LCD's are as follows: [1] LCDs are economical. [2] They are easily programmable. [3] A number of characters can be displayed. [4] Very compact and light. [5] Low power consumption.

A 20x4 LCD means it can display 20 characters per line and 4 such lines are there. In this LCD every character is displayed in 5x7 pixel matrix. LCD possesses two registers: Data and Command registers. The command register stores the command instructions given to the LCD. A command can be defined as an instruction given to LCD to do a predefined task. For example, initializing the LCD, clearing the screen, controlling the cursor position, controlling the display etc. The data register stores the data which is displayed on the LCD screen. The data is the ASCII value of the character which is displayed on the LCD screen.

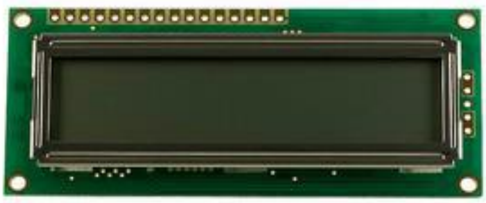

Figure 9. 4×20 LCD Display

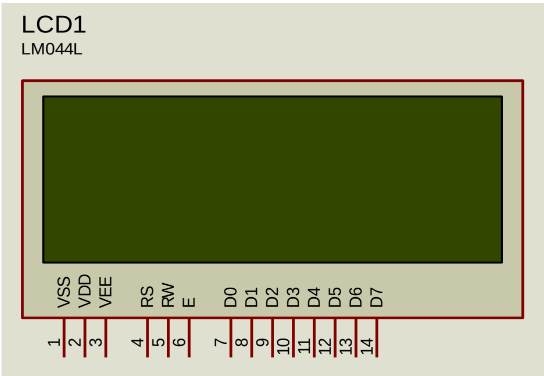

Figure 10. LCD Pin Diagram

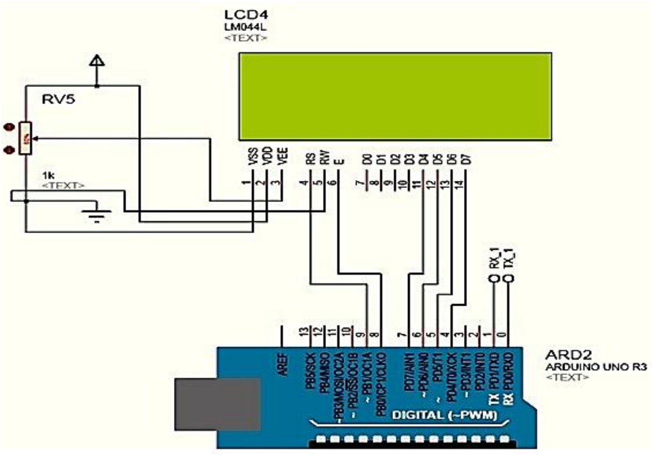

Figure 11. Computer interface with LCD

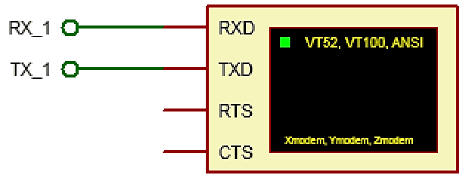

Figure 12. Virtual terminal emulator

The computer interface does the following:

- Supplies 5volts regulated power to the microcontroller through the USB connection
- Serial communication.

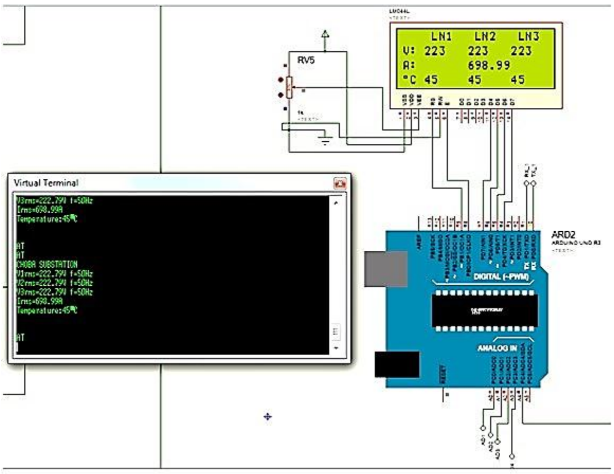

Figure 13. Simulation of virtual terminal

F. GSM MODEM

The GSM modem also requires a SIM card from a wireless carrier to operate.

Figure 14. GSM Modem

SIM 300 is a Fixed Cellular Terminal (FCT) used for data applications. It is a compact and portable terminal which satisfies various data communication over GSM. It also can be connected to a computer with a standard RS232C serial port. SIM 300 offers features like Short Message Services (SMS), Data Services (sending and receiving data files), Fax 21Services and data file connectivity through wire is not available or not possible. The SIM 300 is very easy to set up. It also finds its applications in IT companies, banks, financial institutions, service providers, far away project sites, and other business establishments.

IV. System Simulation, Discussions and Result

This section describes about the software implementation of the research. This discusses about the programming and the software tools used and how output is obtained by programming.

A. Simulation

Some of the tools used in the simulation are listed below:

i. Software: proteus

Proteus (***Pro****cessor for* ***Te****xt****E****asy to* ***U****se*) is a fully functional, procedural programming language created in 1998 by Simone Zanella. Proteus incorporates many functions derived from several other languages: C, BASIC, Assembly, Clipper/dBase; it is especially versatile in dealing with strings, having hundreds of dedicated functions; this makes it one of the richest languages for text manipulation.

Proteus owes its name to a Greek god of the sea (Proteus), who took care of Neptune's crowd and gave responses; he was renowned for being able to transform himself, assuming different shapes. Transforming data from one form to another is the main usage of this language.

ii. Compiler: Sketch
Arduino Software IDE

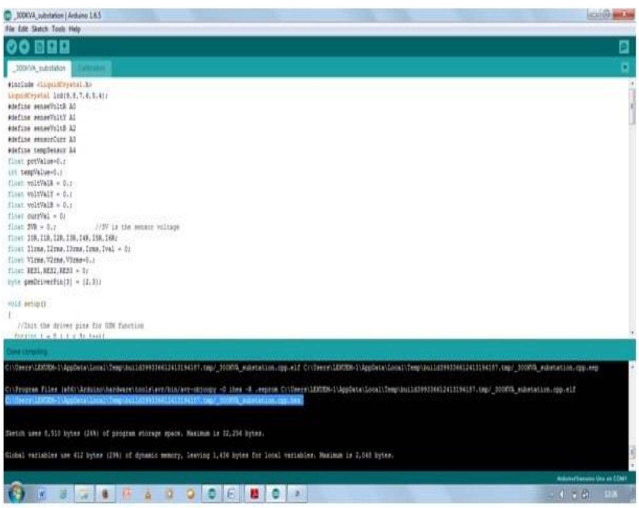

Figure 15. Arduino IDE Software

Arduino programs may be written in any programming language with a compiler that produces binary machine code. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio.

A program written with the IDE for Arduino is called a "sketch". The Arduino IDE supports the C and C++ programming languages using special rules of code organization. The Arduino IDE supplies a software library called "Wiring" from the Wiring project, which provides many common input and output procedures. A typical Arduino C/C++ sketch consists of two functions that are compiled and linked with a program stub *main ()* into an executable cyclic executive program:

B. Programming Microcontroller

The compiler for high level language helps to reduce production time. For programming Arduino Uno, sketch is used. The programming is done in embedded C language. The compilation of the C program converts it into machine language file (.hex). This is the only language the microcontroller will understand, because it has the original program code converted into a hexadecimal format. During this process some errors and warnings occur. If there are no errors and warnings then run the program, the system performs all the given tasks and behaves as expected the software developed. If not the whole procedure is repeated again.

C. Simulation Testing

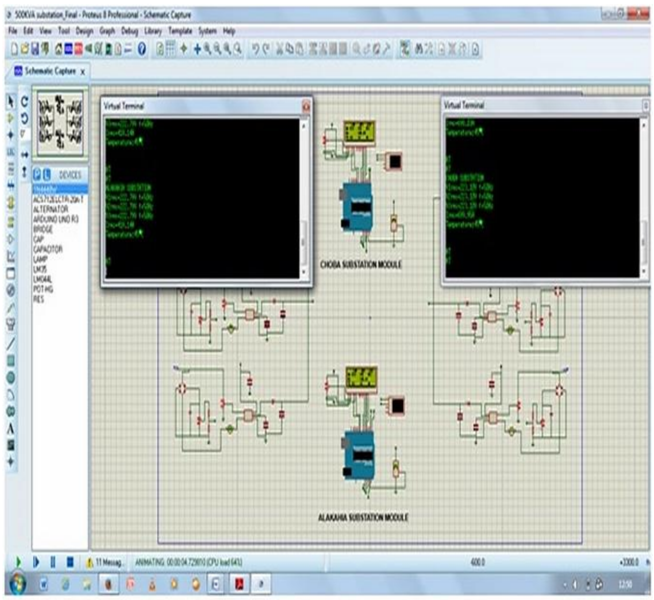

Figure 16. Simulation Model

D. Results

Nameplate rating of Distribution Transformer:
KVA rating: 500
Cooling type: oil natural
Voltage rating:

HV: 11KV

LV: 0.415KV

Current rating:

HV: 26.24A

LV: 695.60A

Impedance voltage: 3.92%

Vector Group: Dy11

Maximum Temperature Rise in oil: 45 deg.C

We need to monitor the phase voltages and the total load current under normal condition.

Total load current is the summation of the three phase current divided by 3 (i.e. the average value of current in the three phases).

$$\text{Load Current} = (I_a + I_b + I_c)/3 \quad (1)$$

E. *Voltage Monitoring*

The main feature of the voltage monitoring ensures rated consumer voltage by providing proper communication with the control station. During fault condition, as per the existing distribution line protection system, the fault current flows through the faulty area and distribution side protection fuses gets tripped depending upon the rate of fault current. During line to earth fault the voltage reduces from its rated value. The threshold value of voltage stored at the Microcontroller instantly acts for the GSM modem to send a faulty message.

The reference voltage is 220.00, so we would vary the voltage between 215V to 240V. Voltage values outside this range triggers an sms to the authorized personnel.

By varying the potentiometer, we change the voltage of each of the phases it is more than the reference voltage…

So the system will send message <Under or over voltage>

The following displays are obtained during the operation.

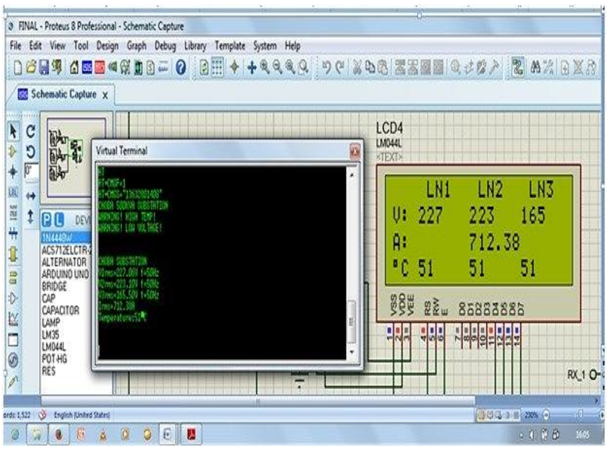

Figure 17. Result of voltage sensing

The power supply to the potentiometer has been rectified to produce a maximum of 5V which is the voltage required by the analog-in-pin of the Arduino microcontroller. Therefore, the potentiometer has been calibrated to indicate the 220V reference voltage from the mid-point of the potentiometer.

F. *Current Monitoring*

The current monitoring aims for the protection of consumers and distribution transformer from fault current and avoid electrical shock through real time sms alert to authorized personnel. The system monitors the load current of the substation.

For a 500kva transformer, load current (I)=500/ (0.415*√3)

$$I=695.6A \quad (2)$$

The Load current can also be calculated by taking the average of the phase currents.

$$I =(I_a + I_b + I_c)/3 \quad (3)$$

Equation 3 is what we have used to design the module.

The reference current is the instantaneous load current. We have set the fault current to ±10% of the instantaneous load current.

By varying the potentiometer connected to the current sensor ACS712, the value of the load current is varied

When current value is more than the reference current of 695.6A… the system will send message <WARNING! HIGH CURRENT>

The following displays are obtained during the operation.

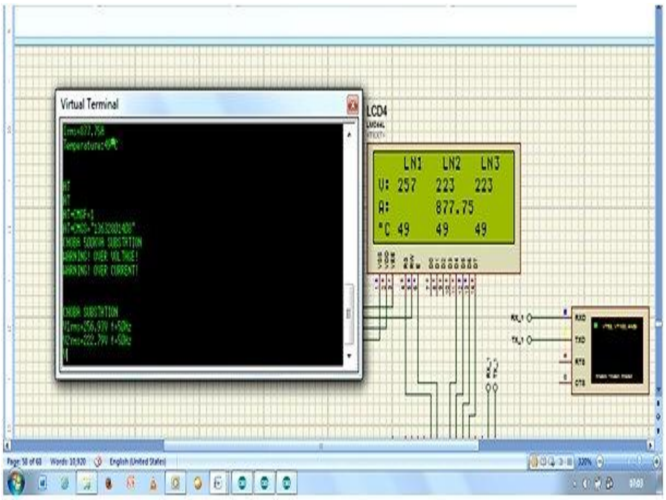

Figure 18. Result of high current sensing

Similarly, when current value is below the reference value, the system will send message <WARNING! LOW CURRENT>

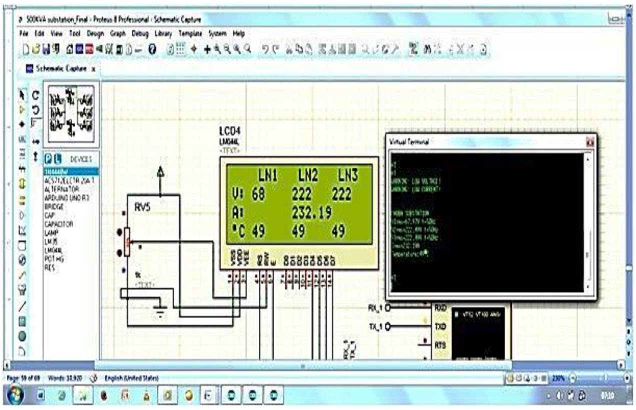

Figure 19. Result of Low Current sensing

G. *Temperature Monitoring*

For proper operation of transformer the temperature should be within the maximum allowable value. During a fault, the current may increase and hence, the temperature also, and may leads to the formation of bubbles in the oil. These bubbles will trap between the windings and results in spark between the windings. So it is important to monitor the temperature of the transformer to ensure safe operation.

The maximum temperature is 45 deg. C. By varying the temperature sensor (LM35) we change the temperature value above the maximum value of 45 deg. C above 50 deg. C, It is more than the reference voltage… So the system will send message <WARNING! HIGH TEMP>

The following displays are obtained during the operation.

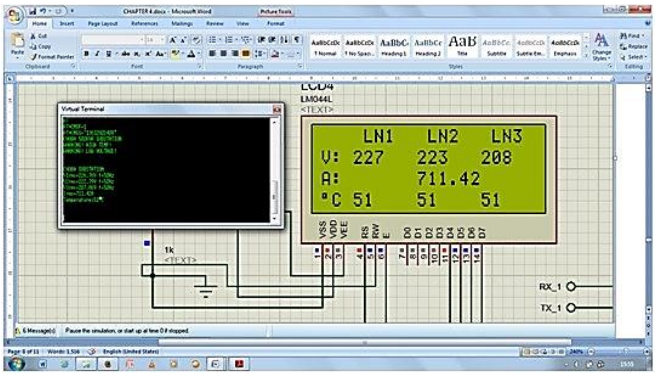

Figure 20. Result of temperature sensing

V. CONCLUSION

The GSM based monitoring of distribution transformer is quite useful as compared to manual monitoring and also it is reliable as it is not possible to monitor always the, oil temperature rise, load current, voltage, etc. After receiving of message of any abnormality we can take action immediately to prevent any catastrophic failures of distribution transformers. In a distribution network there are many distribution transformers and associating each transformer with such system, we can easily figure out that which transformer is undergoing fault from the message sent to mobile. We need not have to check all transformers and corresponding phase currents and voltages and thus we can recover the system in less time. The time for receiving messages may vary due to the public GSM network traffic but still then it is effective than manual monitoring.

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