DIFFERENTIAL PROTECTION OF TRANSFORMER USING ARDUINO WITH GSM AND VOICE CIRCUIT

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Abstract- - Transformers are the important equipment's in the power system. Therefore, the continuity of its operation is very necessary. So better protection scheme should develop for transformers. Differential protection technique can be employed to protect the Transformers. In this paper, we have used differential relay mechanism with GSM module and voice announcement circuit. The GSM and voice circuit is synchronized with Arduino microcontroller. Arduino Microcontroller is very high speed and cost effective device with fine accuracy. By programming in the Arduino the protection of transformers can be done. Programming is quite efficient and easy than 8051 microprocessor used in differential relay mechanism, so it is better to use Arduino place of 8051 microcontroller. The simulation results successfully justified this proposed system in proteus software also.

Index Terms— Transformer, Differential current protection, Arduino ,GSM and voice circuit

I. INTRODUCTION

The transformer is one of the most important links in a power system. And it is a static device which transforms electrical energy from one circuit to another circuit. To protect the transformer from atmospheric dust and dirt, it is totally enclosed and oil immersed. As transformer has no rotating part, the chances of a fault occurring in them are very rare. However, a rare fault may be very dangerous unless the transformer is quickly disconnected from the system. This necessitates adequate automatic protection for transformers against possible faults. Small capacity transformers are provided with series fuses for protection against overloading and earth faults. No circuit breakers are provided. i.e no automatic protection is given. However, the probability of faults on power transformers is more and hence automatic protection is necessary. A fault which occurs beyond the protection zone of the transformer, but fed through the transformer is known as "Through faults". A unit protection of transformer should not operate for through faults. The overload relaying may be provided to operate with a time lag to provide back-up protection. Internal faults are those in the protected zone of the transformer. These faults can be between phase to phase and phase to ground. Generally, they occur due to a failure of insulation due to temperature rise. Incipient faults are initially minor causing gradual damage. These faults grow into serious faults. Incipient faults include loose connection in conducting path, sparking, small arcing etc.

II. TRANSFORMER PROTECTION

A) Over current protection: over current protection is used for the purpose of providing backup protection for large transformers. Two phase fault and one ground fault relay is sufficient to provide overcurrent protection to star delta transformer

B) Protection against over fluxing: The magnetic flux increases when the voltage increases. This results increased iron loss and magnetizing current which leads insulation damage. The expression for flux in a transformer is given by

$$\Phi = K\, E/f \qquad \text{------ (1)}$$

To control flux, the ratio E/f is controlled. When the ratio exceeds a threshold value, it has to be detected. Electronic circuits with suitable relays are available to measure this ratio. Over fluxing does not require high-speed tripping, but the transformer should be isolated in one or two minutes at the most if over fluxing persists.

C) Over Voltage Protection: Lightning overvoltage surges originate from atmospheric discharges and they can reach their peak within a few microseconds and subsequently decay very rapidly. The surge overvoltage can reach up to 10 times the rated transformer voltage and they pose the greatest threat to the transformer on the distribution networks. Protection against surges can be achieved by using "Lightning Arresters".

D) Percentage Differential Current Protection: This scheme is employed for the protection of transformers against internal short circuits and it provides the best overall protection for internal faults. The differential relay operates when there is a difference between incoming quantities and outgoing and if exceed some pre-set value. This difference carried out by using a set of current transformers as shown in the figure. The differential protection has serval drawbacks which are overcome by using percentage differential protection, the problems are listed below:-

1) Magnetizing inrush current

When the transformer is energized, there is no induced e.m.f, the resistance being low and a large inrush of magnetizing current produced. This inrush current is 6 to 8 times higher then peak rated current. But this is for very short duration, hence differential protection should not be operate for inrush current, so 0.2 seconds of time delay setting for this relay, while inrush current gets vanish completely.

2) CT's ratio

Alternator has same ratings of CT's but for transformer, both CT,s will have different ratting because of their input and output voltage is different, and this situation leads to run protection without any fault occur, that will solve by using restraining coil place midpoint of the pilot wire and operating coil will connect to middle of restraining coil as showing in figure. The current flowing through restraining coil can be taken as (I1+I2/2).With increasing in through current the restraining torque also increasing which will grater to the operating torque, hence operating torque is not sufficient to operate the relay.

3) Phase displacement

There is another problem is a phase displacement which is solving by providing below arrangement.

Sr. No.	Power transformer connection		Current transformer connection	
	Primary	Secondary	Primary	Secondary
1.	STAR	DELTA	DELTA	STAR
2.	DELTA	STAR	STAR	DELTA
3.	STAR	STAR	DELTA	DELTA
4.	DELTA	DELTA	STAR	STAR

Table 1 – Connection Arrangement Of Power Transformer And Current Transformer

E) Incipient Fault Protection: Faults which are not serious at the beginning but which slowly develops into serious faults are knows as incipient faults i.e. tank oil temperature gradually increased which is taken care by "Buchholz Relay". [1] [3]

III. ARDUINO

AVR is better than 8051 microcontrollers. AVR is an Atmel which is used in Arduino board. Arduino is open source hardware and has everything, no need for any external resistor or capacitor. It is cheaper and easy to use, the programming is also very simple. Any system could develop easily with Arduino, and reach library file for designing purpose are easily available. Integrated development environment (IDE) is used for programming which is written in C or C++ language. There are various Arduino board available in the market, but here we used Arduino Uno because it is easy and compatible compare to other, and no need of higher number of A/D pin, so we choose Arduino Uno compared to Arduino Leonardo. Arduino Uno has 14 digital input/output pins 6 analog inputs, 16 MHz ceramic resonator, USB connection, power jack, and reset button. [7] [8]

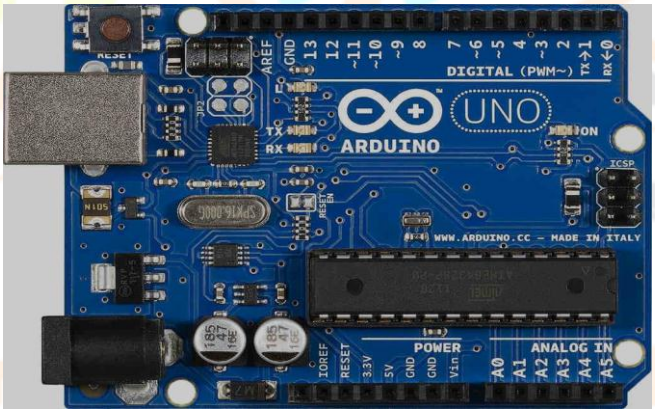

Figure 1 – Arduino Uno Circuit

IV. CURRENT SENSOR

The Current sensor is a hall effect sensor which converts current value to voltage value. Here we used ACS712 current sensor which can measure current up to 30 A. The voltage generated at the output of the current sensor is 66mV/A so this relation is used to determine the value of current by Arduino. However, here 2.5V offset at zero current is present at output of current sensor. The output voltage will be applied to the Arduino which will convert ac to dc. Here we will use two current sensors which will connect to the Arduino board through A0 and A1 pin. Arduino will compare both output values and take action respectively. The Connection will be done as per showing below block diagram. [4]

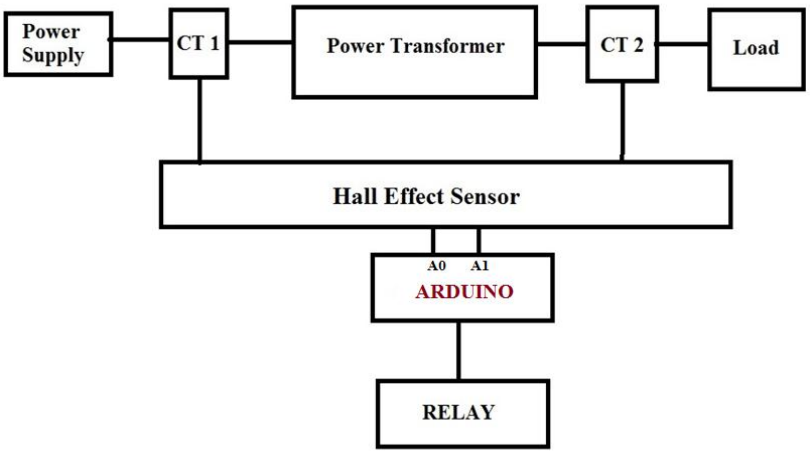

Figure 2 – Block diagram of differential current protection of transformer using Arduino

V. GSM AND VOICE CIRCUIT

GSM (Global System for Mobile Communications) module is a chip or circuit that will be used to establish communication between a mobile device or a computing machine and a GSM system. There are different kinds of GSM modules available in the market. We are using the most popular module based on Simcom SIM900**.** This means the module supports communication in 900MHz band. We are from India and most of the mobile network providers in this country operate in the 900Mhz band. The communication between Arduino and GSM module is serial. You may connect the Tx pin of GSM module to Rx pin of Arduino and Rx pin of GSM module to Tx pin of Arduino. Now connect the ground pin of Arduino to ground pin of GSM module. The modem needs AT commands, for interacting with a controller, which are communicated through serial communication. These commands are sent by the controller. The MODEM sends back a result after it receives a command. Different AT commands supported by the MODEM can be sent by the controller to interact with the GSM. [9]

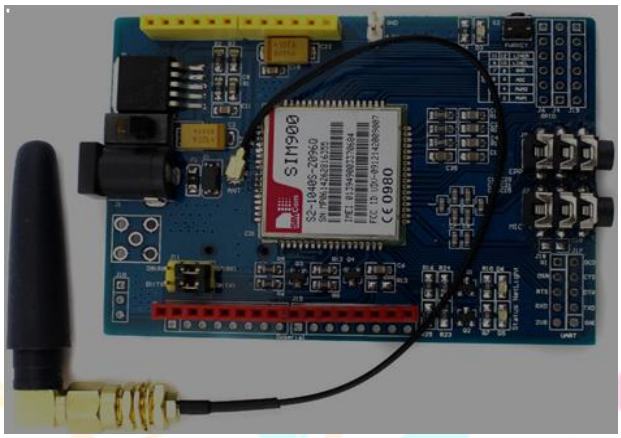

Figure3 - Simcom SIM900 GSM MODULE

The APR33A series are powerful audio processor along with high performance audio analog to-digital converters (ADCs) and digital-to-analog converters (DACs). The APR33A series are a fully integrated solution offering high-performance and unparalleled integration with analog input, digital processing, and analog output functionality. The APR33A series incorporates all the functionality required to perform demanding audio/voice applications. High quality audio/voice systems with lower bill-of-material costs can be implemented with the APR33A series because of its integrated analog data converters and full suite of quality-enhancing features such as sample-rate convertor. [10] [11]

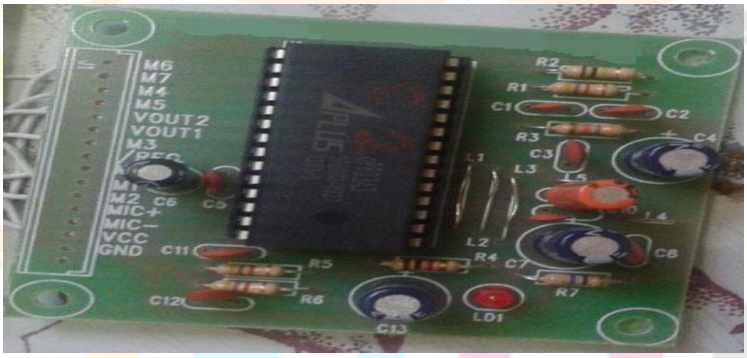

Figure 4 – Voice Circuit

VI. WORKING OF MICROPROCESSOR BASED RELAY

Here Arduino is used as a brain. The circuit diagram as shown in below diagram. Here we used two current sensor ACS712 is which is connected to the Arduino through A0 and A1 pin. This relay is used to initiate the voice circuit which gives voice alert. Here we used 12v DC 1-phase relay which is connected to the 13 no pin of Arduino. As we can see GSM and voice circuit also integrated with Arduino.

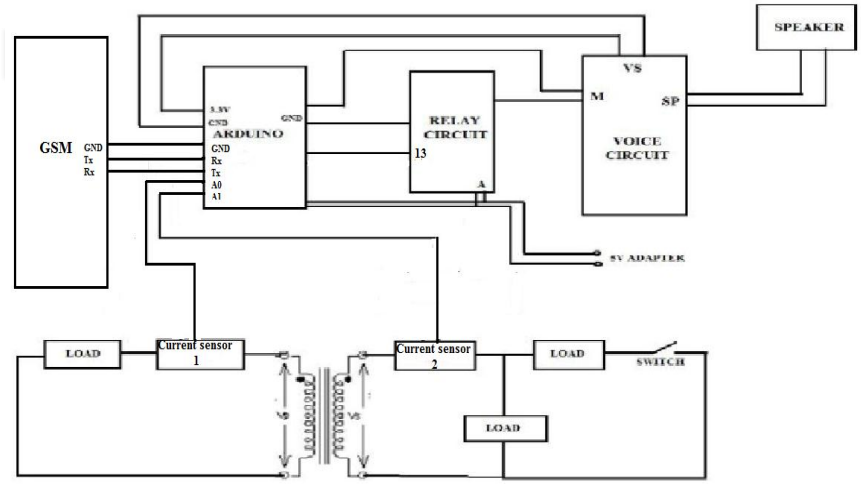

Figure 5 – Circuit Diagram Of This Proposed System

Under normal operating conditions currents on primary and secondary are same. So, the proportionate voltages generated by the current sensors on primary and secondary are same. These two voltages will be applied to the Arduino. Under normal operating conditions these two voltages will be same in magnitude and difference is zero. So, the Arduino gives no signal to the relay.

Whenever internal fault occurs in transformer the currents seen by the Current sensors on primary and secondary differs by some amount. As a resulting voltage sensed by the Arduino from primary and secondary differs. As there is a difference in the voltage sensed by the Arduino. Arduino give a signal to the relay according to predefined program. And when the relay is activated by the Arduino the relay will activate the voice announcement circuit. The voice circuit will give output predefined voice as alert to the operator. After three consecutive voice alerts Arduino will give a trip signal to the relay board and which is connected in series with the supply will open its contacts thus the supply to the hardware setup will be disconnected. And GSM will send a message showing a current different and place of which one transformer getting the fault to the operator. And also operator can perform the respective action for faulty transformer from anywhere through sending a message back to the GSM.

Some faults happen to the transformer which is not a harmful for the system, so for that condition power transformer should not isolate from the power system, so here we designed system for such situation. Let we choose allowed current difference is 0.5 amp, so at that difference GSM send a message to the operator like INTERNAL FAULT ON TRANSFORMER T1 DUE TO CURRENT DIFFERENCE OF 0.5 PLEASE GIVE A MISSED CALL ON THE SAME NUMBER TO ALLOW THE SUPPLY.so when operator give call to GSM the system will automatically back to the operation.

And when serious faults like short circuit of winding happens the current difference will increase to allowed difference 0.5 so GSM will send a message to the operator like INTERNAL FAULT ON TRANSFORMER T1 DUE TO CURRENT DIFFERENCE OF >0.5 PLEASE SOLVE THE ISSUE, so now if operator give call to GSM the transformer will not get back to operation so operator will have to visit site personally to solve the issue.

VII. ARDUINO PROGRAMMING

```
const int sensorIn0 = A0;
 const int sensorIn1 = A1;
 int relayPin = 13;
 int mVperAmp = 185;

          double Voltage0 = 0;
          double VRMS0 = 0;
          double AmpsRMS0 = 0;

          double Voltage1 = 0;
          double VRMS1 = 0;
          double AmpsRMS1 = 0;
          double Diff = 0;

          char val=0;.
          double ADiff=0.05;
          double Voff = 0;
          void setup()

            {
Serial.begin(9600);

          pinMode(relayPin, OUTPUT);
          digitalWrite(relayPin, LOW);
          Serial.print("AT");
          Serial.print((char)13);
          Serial.print((char)10);
          Serial.print("AT+CMGF=1");
          Serial.print((char)13);
          Serial.print((char)10);
          Serial.print("AT+CLIP=1");
          Serial.print((char)13);
          Serial.print((char)10);

          }

void loop()
          {

           Voltage0 = getVPP0();
           VRMS0 = (Voltage0/2.0) *0.707;
           AmpsRMS0 = (VRMS0 * 1000)/mVperAmp;
           Serial.print(AmpsRMS0);
           Serial.println(" Amps RMS");

           Voltage1 = getVPP1();
```

```
          VRMS1 = (Voltage1/2.0) *0.707;
          AmpsRMS1 = ((VRMS1 * 1000)/mVperAmp)*29.5;
          Serial.print(AmpsRMS1);
          Serial.println(" Amps RMS");
         Diff=AmpsRMS0-AmpsRMS1;

if(Diff<ADiff)

          {digitalWrite(relayPin, LOW);}

          else if(Diff>ADiff & Diff<5)

          {

             relay();

          Serial.print("AT+CMGS");
          Serial.print('=');
          Serial.print("");
          Serial.print("9601611015");
          Serial.print("");
          Serial.print((char)13);
          Serial.print((char)10);

delay(1000);

         Serial.print("INTERNAL FAULT ON TRANSFORMER TX1 DUE TO CURRENT     DIFFERENCE OF ");

            Serial.print(Diff);

         Serial.print("PLEASE GIVE A MISSED CALL ON THE SAME NUMBER TO ALLOW THE SUPPLY");

            Serial.print((char)26);
            val=0;
           do{

if(Serial.available())

            { val=Serial.read();}
            }while(val!='R');
            digitalWrite(relayPin, LOW);
            ADiff=1.5;
          }

else{
            relay();
            Serial.print("AT+CMGS");
            Serial.print('=');
            Serial.print("");
            Serial.print("9428444470");
            Serial.print("");
            Serial.print((char)13);
            Serial.print((char)10);
            delay(1000);

            Serial.print("INTERNAL FAULT ON TRANSFORMER TX1 DUE TO CURRENT DIFFERENCE OF ");

Serial.print(Diff);

            Serial.print(" PLEASE SOLVE THE ISSUE ");
            Serial.print((char)26);
            while(1);
            }
         }
         float getVPP0()
         {
           float result0;
            int readValue0;
```

```
int maxValue0 = 0;
int minValue0 = 1024;

uint32_t start_time = millis();

while((millis()-start_time) < 1000)
{
readValue0 = analogRead(sensorIn0);
if (readValue0 > maxValue0)
{
maxValue0 = readValue0;
}
if (readValue0 < minValue0)
{
minValue0 = readValue0;
}
}
result0 = ((maxValue0 - minValue0) * 5.0)/1024.0;
return result0;
}
float getVPP1()
{
float result1;
int readValue1;
int maxValue1 = 0;
int minValue1 = 1024;
uint32_t start_time = millis();
while((millis()-start_time) < 1000)
{
readValue1 = analogRead(sensorIn1);
if (readValue1 > maxValue1)
{
maxValue1 = readValue1;
}
if (readValue1 < minValue1)
{
minValue1 = readValue1;
}
}
result1 = ((maxValue1 - minValue1) * 5.0)/1024.0;
return result1;
}
void relay(){
digitalWrite(relayPin, HIGH);
}
```

VIII. CONCLUSION

The proposed system operates with GSM based hardware. These Arduino based control system is designed and develop which provides fault identification as well as it is capable to clearing the faults. The overall cost of this proposed system is the major benefit in reference to the conventional system.

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