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Low Cost Miniaturized High Voltage Proximity Detector

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ABSTRACT

The term high voltage usually means voltage above a particular threshold which is high enough to inflict harm or even death upon living things. The International Electro technical Commission (IET, IEEE, VDE, etc.) define high voltage as above 1000 V for alternating current, and at least 1500 V for direct current. Equipment and conductors that carry high voltage warrant particular safety requirements and procedures. Reliably detecting and measuring high voltage on distribution and transmission voltage power lines is vitally important to the jobs performed by electric utility linemen. This task can be done more quickly and safely when the voltage detection and measurement equipment is also convenient and easy to use. The most convenient equipment is usually a single terminal device which operates without a direct connection to ground. In this work we have presented a device which is uniquely designed to fit into safety helmets which accurately detects the presence of high voltage lines from distance range as high as 10 meter. This miniaturized device consists of transistor, Zener diodes and six CMOS based inverters (NOT Gate). The GSM module sets up effective communication with the main control unit and lineman workers which would help maintenance and installation works of substation and power plants

Index Terms— High voltage, proximity detection, NOT gate, GSM, Microcontroller, Transistor, Electric field.

I. INTRODUCTION

The computation of the electrical field distribution around AC high-voltage lines is very important for design of high voltage proximity detector. The International Electro technical Commission (IET, IEEE, VDE, etc.) define high voltage as above 1000 V for alternating current, and at least 1500 V for direct current—and distinguish it from low voltage (<50 V AC or <120 V DC) circuits[1],[2]. The method used to calculate Electric Filed is a semi numerical method using the laws of electrostatic techniques to simulate the two dimensional electric field under the high-voltage overhead line.

High-voltage overhead lines generate electric and magnetic fields in their neighborhood. The magnetic field is caused by phase conductors and the electric field is caused by the high potential of the conductors. In the course of planning high-voltage AC lines, the electric field quantity around the power lines has to be examined to avoid EMC problems. In installations, the electric field should be limited by the safety distances with respect to the conductors Electrical transmission and distribution lines for electric power always use voltages significantly higher than 50 volts, so physical contact with or close approach to the line conductor presents a danger of electrocution.

Digging into a buried cable can also be dangerous to workers at an excavation site. Digging equipment (either hand tools or machine driven) that contacts a buried cable may energize piping or the ground in the area, resulting in electrocution of nearby workers. A fault in a high-voltage transmission line or substation may result in high currents flowing along the surface of the earth, producing an earth potential rise that also presents a danger of electric shock. Exposure to high voltage is also found to have serious consequences on health [3].

Unauthorized persons climbing onto the power pylons or electrical apparatus are also frequently the victims of electrocution. At very high transmission voltages even a close approach can be hazardous, since the high voltage may spark across a significant air gap.

For high and extra-high-voltage transmission lines, specially trained personnel use ‗live line' techniques to allow hands-on contact with energized equipment. In this case the person is electrically connected to the high- voltage line but completely insulated from the earth so that he is at the same electrical potential as that of the line. Since training for such operations is lengthy, and still presents a danger to person, only very few important transmission lines are subjected to maintenance when they are live.

In all other situations, insulation from earth does not guarantee that no current flows to earth—as grounding or arcing to ground can occur in unexpected ways, and high-frequency currents can burn even an ungrounded person. Thus equipment and conductors that carry high voltage warrant particular safety requirements and procedures. Reliably detecting and measuring high voltage on distribution and transmission voltage power lines is very important for maintenance work by electric utility linemen. This provided us an impetus to propose and design a low cost, high precision safety device for electric lineman workers.

This user-friendly device which is uniquely designed to fit into safety helmets, accurately detects the presence of high voltage lines from distance range as high as 10 meter. This miniaturized device consists of transistor, Zener diodes and six inverter circuits which have high noise immunity, and symmetric controlled rise and fall times. The GSM module sets up effective communication with the main control unit and lineman workers which would help in maintenance and installation works of substation and power plants.

II. (A) ELECTRIC FIELD

The space around a charge or a group of charges electric field. The space surrounding a charge or a group of charges in which another charge experiences a force is said to contain an electric field. A test charge placed at any point in the field experiences a force. The electric intensity at any point in an electric field is given by the force experienced by a unit positive charge kept at that point.

If a charge ‗q' is placed at a point where the electric intensity is ‗E', the force experienced by the charge is

$$F = E \times q \qquad E = \frac{F}{q}$$

Thus, the electric intensity at any point is defined as the force per unit positive charge when a test charge is placed at that point. The S.I. unit of electric field is Newton/coulomb (N/C). Let P be a point at a distance ‗r' from a point charge ‗q' in free space. Let a unit positive charge (UPC) be imagined at P. Then by definition, the force on the UPC is the electric intensity.

$$E = \frac{q \times 1}{4\pi\varepsilon r^2}$$

If there are number of charges to produce electric fields at a given point, then the resultant field at that point is given by the vector sum of the individual field strengths. Similar to the gravitational potential energy of a body above the surface of the earth, a charge will have a potential energy in an electric field. Potential energy is taken to be ZERO at infinite distance from a charge or group of charges which produce the field. The electric potential at a point in an electric field is given by the work done in bringing a free isolated unit positive charge from infinity (point of zero field) to that point against the field direction. The electric potential at a point in an electric field is defined as the potential energy stored by a unit positive charge placed at that point Let a unit positive charge be moved from A to B through a small distance dx, against the field direction. Then the work done in this process is

$$dW = \frac{1}{4\pi\varepsilon}\frac{q}{x^2} \times (-dx)$$

The negative sign indicates that the work is done against the field; ‗ dx' is so small that the force can be assumed to be Then the total work done in bringing a unit positive charge from infinity to P is given by constant over it. Let ‗P' be appoint at a distance ‗r' from +q

$$W = \int_{\infty}^{r} dW = \int_{\infty}^{r} \frac{-1}{4\pi\varepsilon}\frac{q}{x^2}dx = \frac{-q}{4\pi\varepsilon}\int_{\infty}^{r}\frac{1}{x^2}dx = \frac{-q}{4\pi\varepsilon}\left[\frac{x^{-1}}{-1}\right]_{\infty}^{r} = \frac{q}{4\pi\varepsilon}\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$\text{Thus } W = \frac{1}{4\pi\varepsilon}\frac{q}{r}$$

Then by definition, the electric potential at P is given by the amount of work to be done in bringing a free isolated unit positive charge from infinity to P against the field direction Where $\varepsilon = \varepsilon_o \varepsilon_r$ and ε_o is the absolute permittivity and ε_r is the relative permittivity.

II.(B) INVERTER (NOT GATE)

The CD4069 consists of six inverter circuits as shown in Fig.1 and is manufactured using complementary MOS (CMOS) to achieve wide power supply operating range, low power consumption, high noise immunity and symmetric controlled rise and fall times. This device is intended for all general purpose inverter applications. All inputs are protected from damage due to static discharge by diode clamps to VDD and VSS. The inverter performs the basic logic operation called as inversion or complementation. The purpose of the inverter is to change the one logic level in to opposite level. This gate has only one input and one output.

II.(C) MICROCONTROLLER

PIC16F688 is 14-Pin Flash-Based, 8-Bit CMOS microcontroller shown in Fig.2 with Nano-Watt Techn and a high-endurance Flash/EEPROM cell.

It has operating speed of DC–20 MHz oscillator/clock input and DC – 200 ns instruction cycle

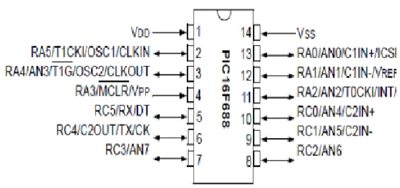

Fig.2: Pin Details of PIC Microcontroller

III. CONSTRUCTION

The circuit of HV proximity detector is a simple circuit which is built using a hex inverter CMOS IC CD4069 as shown in Fig. 3 & Fig.4. It has six inverters (NOT gate). One end of the probe is placed in electromagnetic field and other end is connected in series with R1. Resistor R1 is connected to pin no. 1 of the IC (Input A) and Pin no 2 and 3 are shorted. Cathode of the diode D2 is connected to pin

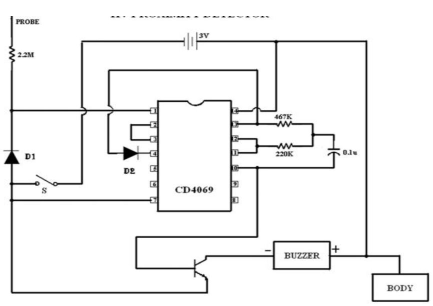

Fig.3: Block diagram of Proximity detector

no. 4 and anode is connected to pin no. 13 and Pin no. 1 is grounded through the diode D1 and Pin no. 12 is shorted with pin no. 11. Resistor R2 & R3 connected in the form of voltage divider circuit as shown in the figure above. Resistor R2 & R3 along with the capacitor C1 forms the timing circuit. Pin no. 10 (output E) is connected to base terminal of the transistor. Output circuit comprises of components such as transistor, buzzer, switch and battery.

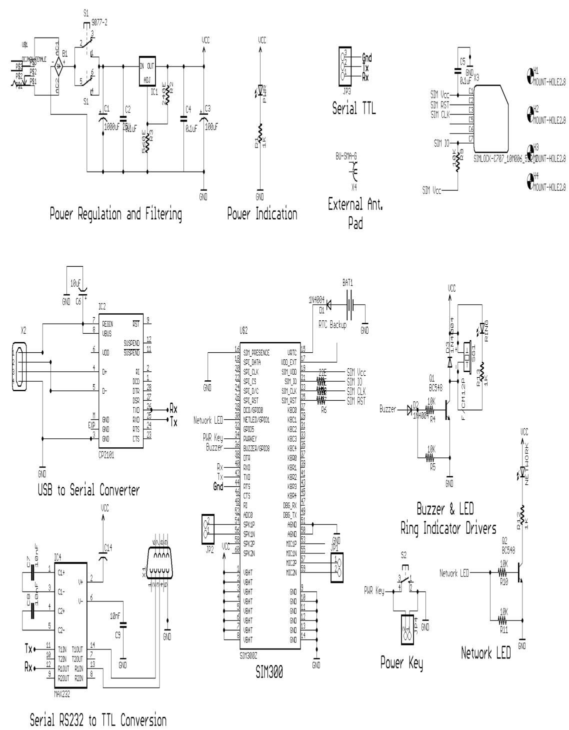

Fig.4: Details of the designe circuit.

Here a transistor is employed as an electronic switch. Operating a transistor as a switch means operating the switch either in saturation or cut-off, but nowhere else in the load line because when in saturation condition the transistor act as a closed switch, while in cut-off it is like an open switch. The entire circuit is powered using a 3V battery. The piezo buzzer provided in this circuit gives a beep sound when a HV line is active near the device.

A piezoelectric buzzer is a device that uses the piezoelectric effect to detect acceleration, force strain, or pressure, by converting them to an electrical signal. It is a versatile device for the measurement of various parameters. It has very high DC output impedance and can be modeled as a proportional voltage source and filter network. This sensing technology is not sensitive to electromagnetic fields and radiation, thus enabling measurements under harsh conditions. The operating voltage range for this piezo buzzer is from 3V to 220V.

The microcontroller and high voltage proximity detector is powered up using 5 volts regulated supply but the GSM module is powered using 4V. The voltage gets regulated from 12 volts to 4 volts using a regulator circuit. A sliding switch is provided to control the powering of the circuit. The LED is planted with GSM module to indicate the working of the model.

IV. WORKIN

This miniaturized prototype consists of six CMOS inverter circuits, transistor and Zener diodes.

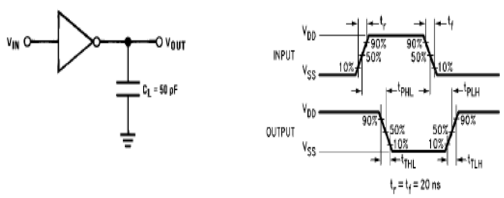

Fig.5: NOT Gate Functioning Diagram

Inverters N1 and N2 are used to sense the presence of 230V AC field around the live wire and buffer weak AC voltage picked from the test probe. The voltage at pin 10 of inverter N2 can enable or disable the oscillator circuit. If we connect two inverter gates together such that the output of one is fed into the input of another, the two inversion functions would cancel out each other so that there would be no inversion from input to final output. While this may look like a pointless thing to do, it does have practical implication. The gate circuits act as signal amplifiers, irrespective of the logic function they may perform.

A weak signal source may be boosted by means of two inverters. The logic level is unchanged, but the full current-sourcing or -sinking capabilities of the final inverter are available to drive a load resistance if required.

When the test probe is away from an AC high-voltage field, output pin of inverter N2 remains low. As a result of this, D3 conducts and blocks the oscillator circuit from oscillating. Simultaneously, the output of inverter N3 at pin 6 will go ‗ low' to cut off transistor T1. As a result, LED1 will switch off. When the test probe is moved closer to 230V AC, live wire of 50Hz mains, during every positive half- cycle, output pin 10 of inverter N2 will go high.

Thus during every positive half-cycle of the mains frequency, the oscillator circuit is allowed to oscillate at around 1 kHz, making the LED to blink. The pins N5 and N6 acts as pulse generators in to sense and buffer the weak voltages. The frequency is determined by timing components consisting of resistors R3 and R4 and capacitor C1. This kind of blinking reduces continuous consumption of power from button cells used to supply power. Simple pulse generators usually allow control of the pulse width, pulse frequency, delay with respect to an internal or an external trigger. These oscillators generate a continuous output voltage waveform at a required frequency with the values of the resistors, inductors or capacitors forming a frequency network. The transistor T1 acts as a switch which is used to energies the piezo buzzer.

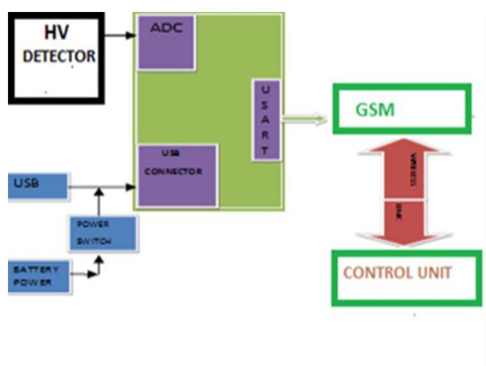

Fig. 6: Block Diagram of the Model

Fig. 7: The Module fitted inside a Safety Helmet

The voltage across buzzer is fed to microcontroller pin 0 through ADC channel. The program is burnt into the microcontroller to activate the GSM module and to detect the type of High Voltage System based on the analog voltage value received by the microcontroller.

The pin 0 is programmed to receive analog value using the program. This analog value is then converted to a corresponding digital value through an analog to digital converter. Depending on the digital data read by the microcontroller, it activates the corresponding message and through GSM transmits the information to control unit. The control unit receives the message and some suitable action is carried out.

The GSM has been intelligently programmed and microcontroller controls the operation and functionality of GSM. The inbuilt ADC in the microcontroller is used for execution of the program.

The communication is set up through USART pins (Rx and Tx) pins of the module. The baud rate of communication is set up to 9600.The ADC Pin 0 is activated through which analog voltage value are fed. Further the analog values are converted to digital values by ADC.

The GSM is made functional mainly through a three step process.

- AT This command initializes the GSM module and thus it starts communication with the microcontroller.
- "AT+CMGS=";

This command instructs the GSM module that the user wants the GSM module to send information to desired subscriber through message format. It sets up GSM module toreceiverequiredmessage to be communicated from the user.

- AT+CMGF=1

This command instructs the GSM module that the subscriber would feed the subscriber information through a contact number. It sets up GSM module to receive a contact number from user.

Finally the phone number is fed which is loaded on to GSM.

- Enter is entered through 0d command

The program is basically constructed using while loop and if conditions format. The while looping format is used in the program and when condition is executed the pointer comes out of the while loop. The If conditions which is placed in the while loop is continuously checked based on the received ADC values. Based on the ADC values received, the particular loop is executed and the corresponding message is delivered to the recipient. These are three conditions that are continuously checked.

- If ADC value is greater than 60 then
The message ―LINE VOLTAGE >= 6.6KV, SO TURN OFF‖ is sent to the control unit.

- If ADC value is between 28 and 55 then The message ―TURN OFF THE 440V SUPPLY LINE‖ is sent to the control unit.

- If ADC value is between 20 and 25 then
The message ―TURN OFF THE 220V SUPPLY LINE‖ is sent to the control unit.

V. RESULT AND DISCUSSION

The prototype has been successfully

tested with different magnitude of voltages and it has been found to work very efficiently. The test results are tabulated in the Table. 1. The high voltage proximity detector has been able to detect the voltage levels from 220 V to 11 kV with accuracy.

TABLE1: TABLE SHOWING THE VOLTAGE PROXIMITY DETECTION

Voltage Detection AC values)	Angle	Distance for Detection
230 V	900	1 cm
440 V	900	15 cm
1000 V	900	50 cm
5000 V	900	70 cm
8000 V	900	85 cm
11,000 V	900	120 cm

VI. CONCLUSIONS

In this work, we have proposed and developed a prototype of simple, cost effective miniaturized high voltage proximity detector which is capable of detecting a wide range of high voltages from 220 V to 11kV.

This integrated kit consisting of high voltage proximity detector, GSM module and the power regulator circuit can be fitted into the safety helmet. This intelligent helmet will detect any energized high voltage line in the vicinity and alert the user.

This device can also be used to check live cables, find fault in flexible cables and to detect any residual or induced voltages.

The future enhancements might include, an advanced low power communication modules like Wi-Fi or Bluetooth Technology and also replacing the present SMS module in GSM with Voice-Over Message system or Calling Function system.

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