Design and Fabrication of Electrostatic Detection Device

Curtis Fennell, Jake Roberts, Jaylen McIntyre, Karim Karkar, Logan Hughes, Samuel Bedgood, Timothy Miller, Tyler Roberts, and Jafar F. Al-Sharab

Department of Engineering Technology
Northwestern State University of Louisiana, Natchitoches LA, 71457

Contact: jafar@nsula.edu

Abstract

Static charges are generated due to friction between different objects. When the accumulated charges start flowing due to sudden contact, an Electro Static Discharge or ESD occurs. Although, this phenomenon is not new, its effect still persistent in many industries and it is far more of a problem now than it has ever been. The ESD has a great potential to damage current electronics especially with the shrinkage of transistor size (below 10 nm). In addition, when there are flammable gases or a high concentration of oxygen, the ESD represents a very dangerous scenario and a spark could ignite the gases and cause an explosion. This research project addresses the design and implementation of feasible and portable electrostatic device, which has the capabilities of detecting electrostatic charges, determining their type, and quantifying them. The design utilizes MOSFET technology with dual N and P channels to detect charges. Preliminary results with examples from gas transporting in pipelines will be discussed. This project is a collaboration of senior design project with Atmos Energy. Atmos Energy spends effort to ensure that safety is the highest priority. Initial prototype of the devices is already fabricated, however, this work is still in progress to quantify charges accurately.

Introduction

Atoms Energy is committed to being the safest natural gas provider in the nation. This commitment includes the safety of its employees, customers and communities. Pipelines carry natural gas around the clock to more than 71 million homes and business in the United States (Atmos Energy safety guide). Pipelines method of transportation is one of the safest forms of transportation and they are involved in far fewer serious incidents that other transportation methods such as trucks, railroads, ships or airplanes. However, the transportation of gas at high speed in pipelines generates electrostatics charges that accumulate at the surface of pipelines. The hazard behind electrostatic discharges can be very dangerous and the effects could be life-threatening especially in the case of gas leak. Many accidents including large disasters are triggered by electrostatic discharge.

This project involved in the design and fabrication of portable electrostatic device that is capable of detecting electrostatic charges and quantifies them.

Figure 1, Static Spark Ignites Explosion Inside Flammable Liquid Storage Tank (source: Internet, CSB: Barton Solvents Case Study)

Objectives

The major objective of this project is to design and fabricate a portable electrostatic detection device which will help in

- Increasing the overall facility and job site safety.
- Increasing the technician safety and understanding of electrostatic discharge events
- Quantify electrostatic charges

The project also proposes techniques to mitigate and suppress ESD and to promote safety

Circuit Design and Simulation

Figure 1 displays Multisim design of electrostatic device circuit. The basis of detection of electrostatic charges involves Field Effect Transistors (FETs). FETs are basically transistors that uses an electric field to control the electrical behaviour of the device. For this project, a Mode Power Field Effect Transistor (MOSFET) chip with Dual N and P Channels was used. The two LEDs in the circuit used as indicators for the positive (N-channel or red LED) and negative charges (P-channel or blue LED).

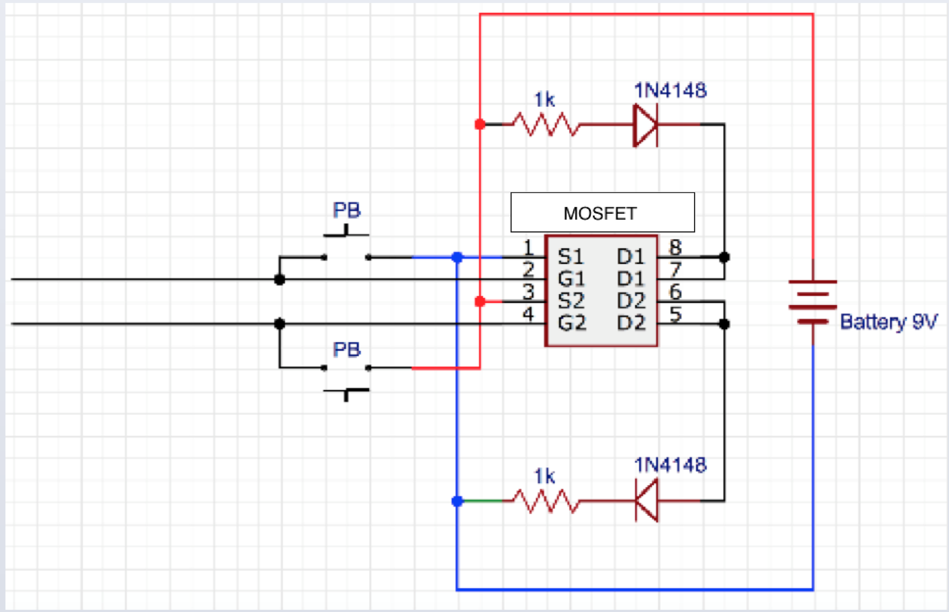


Figure 1, Circuit Diagram showing MOSFET Integrated Chip used in the design

Device fabrication

Figure 2 shows the complete circuit on a breadboard. A 9 volt battery was used for the ease of portability and to enhance sensitivity of the device. Two mini voltmeters were added to the design in order to read the voltage across the individual LED's and to help quantifying the accumulated charges.

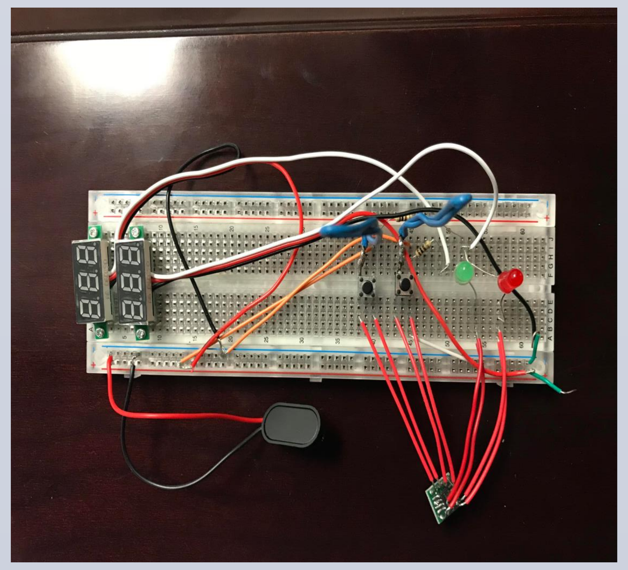


Figure 3, A photo showing the main components of the circuit including voltmeter, reset buttons, and LED indicators (for +ve and –ve charges)

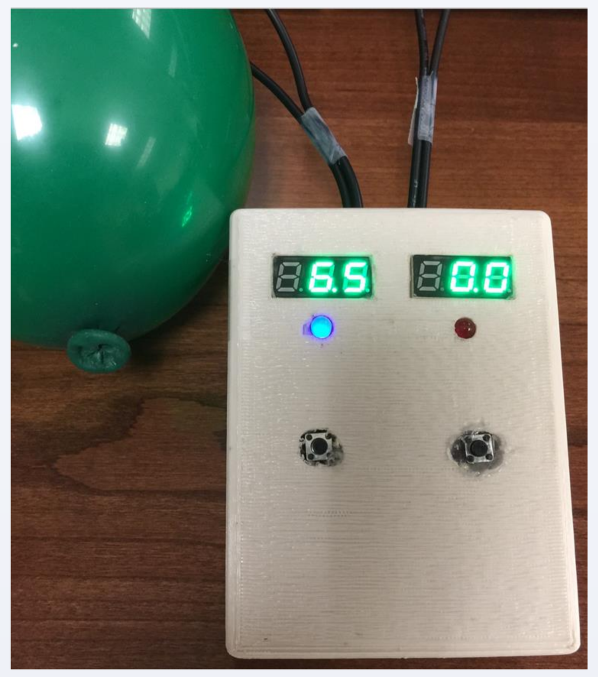


Figure 4, The assembled device in 3D-printed chassis. The device is detecting negative charges by rubbing a balloon on hair (blue LED indicator, 6.5 Volt)

Device Sensitivity testing

Time spent rubbing balloon	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
15 seconds	42.86	63.5	25.4	47.63	82.55	52.388
30 seconds	63.5	44.45	82.55	63.5	57.15	62.23
60 seconds	139.7	158.75	127	130.75	106.36	132.512

*measurements taken in mm

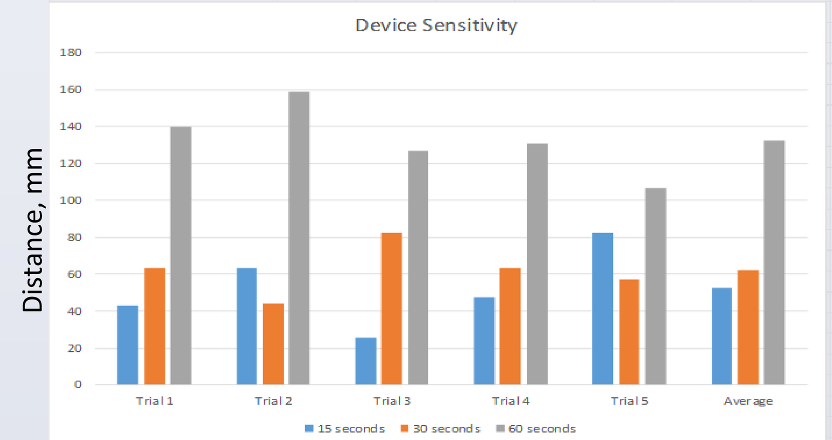
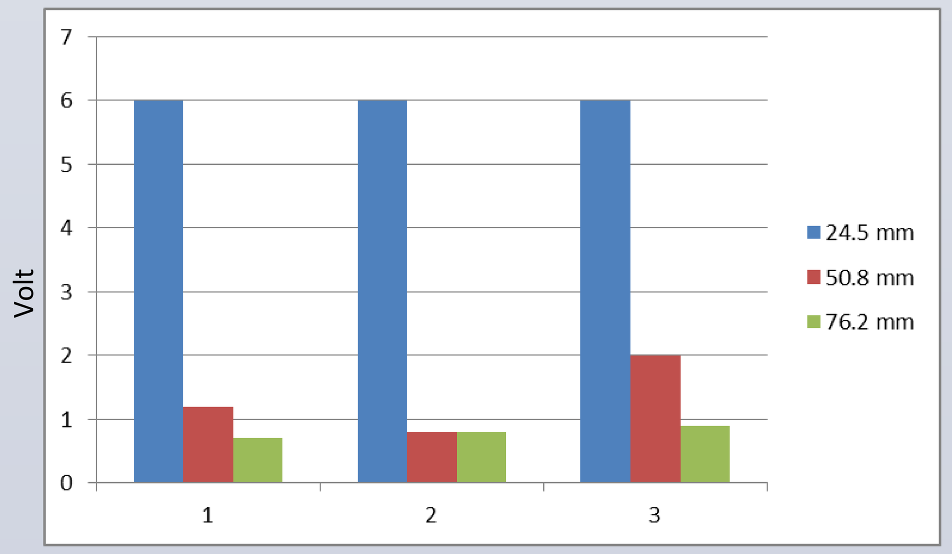


Figure 5, Device sensitivity test (Effect of time and distance on detection of electrostatic charges)

In this experiment, static charges were generated by rubbing a balloon against a piece of hair for a period of 15 seconds, 30 seconds, and 60 seconds. 5 trials were conducted for each period of time. In each trail, the balloon was brought slowly to the EDD. When first detection occurred, the distance was recorded.



Distance between pipe and EDD (mm)	Trial 1	Trial 2	Trial 3	Average
25.4	6	6	6	6
50.8	1.2	0.8	2	1.333333
76.2	0.7	0.8	0.9	0.8

* measurements taken in voltage

Figure 6, Device sensitivity test for polyethylene pipe

The EDD was used to detect the static charge build-up on polyethylene (PE) pipe. The PE pipe was rubbed with a towel for 30 seconds and then the pipe was placed one inch, two inches, and three inches from the EDD. The voltage across the LEDs was measured (using the mini voltmeters) at 1", 2", and 3". At each distance, three measurements were obtained for a total of nine measurements.

Quantification of Electrostatic Charges

Through out this project, three prototypes were fabricated. The latest prototype demonstrated the best sensitivity. Quantification of charges could be estimated from the following equation [A Küchler, 2009] :

$$\oint_{A} \varepsilon_0 \varepsilon_r E \, dA = q$$

This equation is based on Maxwell's equation where E is the field strength, ε_0 is a natural constant and has a value of 8.8452 x 10^{-12} As/Vm, and ε_r is the relative permittivity, which is material dependent (always greater than zero)

The main challenge in this work is the quantification of electrostatic charges since it requires sophisticated analysis. Nevertheless, we propose this for future improvement.

Summary and conclusions

- A portable electrostatic detection device was designed and fabricated
- Experiments to test the sensitivity of the device were carried out
- 3D-printing was utilized to fabricated a functional chassis for the ED device
- Close proximities tend to saturate the EDD voltage indicator
- As expected, electrostatic discharges increases with increasing time friction time
- In the case of accumulated charges on a balloon, the farthest detectability occurred at 132 mm when the total time of friction last for 60 seconds.
- Sensitivity of the device was improved by using 9 volt battery
- Multisim is a very useful tool to design and test circuits before fabrication
- Accurate quantification of electrostatic charges is still required
- ESD can be minimized using proper grounding, antistatic spray, or internal static suppression cartridges. The later is the most efficient - and expensive - technique.

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