Development of LVDT (Linear Variable Differential Transformer) sensor as land displacement sensor

Wilson Jefriyanto¹,*, Bergita Gela M Saka¹, Martina Pineng² and Mitra Djamal³

¹Department of Physics, Univeristas Kristen Indonesia Toraja, Makale, Indonesia
²Department of Electrical Engineering, Univeristas Kristen Indonesia Toraja, Makale, Indonesia
³Department of Physics, Institut Teknologi Bandung, Bandung, Indonesia

*wjefriyanto@ukitoraja.ac.id

Abstract. In mitigation, one of the sensors used is the sensor to observe the movement of land in anticipating of a landslide that occurs in Indonesia. This research has been developed Linear Variable Differential Transformer (LVDT) sensor that is a position sensor to serve as land displacement sensor. The development of LVDT sensor has been developed and has started to be produced in prototype, but the price is expensive, therefore in this research used the material that is affordable so that the price is cheaper. This LVDT sensor has the smallest scale specification is 0.1 mm with a measurement range up to 140 mm. For testing of this sensor by making experimental simulations using a container measuring. The container is tilted to an angle with varying angle of 40°, 45° and 50°. The results of land displacement experiments at angles of 40°, 45° and 50° are 5.5 mm, 27.6 mm and 28.3 mm. This data shows the angle of the ground is directly proportional to the magnitude of landslides.

1. Introduction

The development of sensors is currently advancing with the development of technological systems and the types of materials used. Besides, the need for sensors and sensor systems are not only in the industrial field, but also penetrated in other fields, such as the automotive, processing technology, the building, medical, communication, information technology, and other fields. One type of sensor developed at this time is a sensor to determine changes in a land shift to anticipate the occurrence of landslides which is a natural disaster that is happened in Indonesia [1].

Observation of soil movement has been developed with several instrument instruments including electric extensometer, inclinometer and Fiber Bragg Grating (FBG) strainmeter. In the detection of compressive power between soil layers using the FBG strainmeter sensor. The Inclinometer to detect the relative movement of the soil layer. Whereas electric extensometer to detect ground level shifts [2, 3, and 4].

An instrumentation and monitoring system for ground shifts using a microcontroller-based LVDT sensor has been developed [5]. LVDT (Linear Variable Differential Transformer) sensor is one of the magnetic sensors commonly used as a displacement sensor. This sensor consists of a secondary coil and a primary coil that are powered by an AC current to produce magnetic induction. Inside the sensor there is an iron core (ferromagnetic material) which will induce a secondary coil resulting in magnetic flux, resulting in an output voltage that is proportional to the position of the iron core. The ability of sensors to determine this position, can be developed into an instrument that can observe the land displacement.
2. Principle of LVDT Sensor
The LVDT sensor works based on the principles of the differential transformer where the variable is determined by the pair of primary-secondary winding present in this sensor. This LVDT sensor was first pioneered by Schaevitz in 1940. Since then these forms of sensor have been widely developed and applied in various purposes. In addition, LVDT has also been modeled and analyzed with electromagnetic field theory. LVDT performance is determined by the transducer geometry, excitation variation, current and frequency to determine the proposed performance [6].

![Figure 1. The Coil on the LVDT Sensor](image)

This LVDT sensor can be seen in Figure 1, where the primary winding is connected to an AC current source, with a sinusoidal signal that will make the secondary winding generated with an induced voltage [3]. Since the secondary winding is installed in series, the output voltage (signal) of the secondary winding pair is the result of the difference of the two secondary voltages [7].

On the LVDT sensor which consists of a cylindrical pipe on the inside there is a magnetic bar, consequently if the magnetic bar is not located right in the middle of the sensor, the induced voltage generated in the two secondary windings becomes different, because the magnitude of the induced voltage is determined by fast slow and strong weak magnetic flux in the coil. Moderately weak flux in the coil is affected by the presence of magnetic rods in the pipe. So the position of the magnetic rod in the pipe determines the LVDT sensor's output signal [6].

3. Methodology

3.1. Research Methodology

The overall stages in this study are illustrated in the scheme in Figure 2.

![Figure 2. The stages of LVDT sensor research](image)

Sensor is done manually by using a wire which has a counter coil so that it makes it easier to calculate the number of turns. As for the inside of the pipe there is an iron core (core) from ferromagnetic material that is ferrite. This iron core serves to generate magnetic induction in the secondary coil. The design of this LVDT sensor can be seen in Figure 3.
The LVDT measurement sensor depends on the diameter of the coil and the length of the coil according to Faraday's law. For this reason, variations in pipe diameter, enamel wire diameter, and the number of primary and secondary winding [6].

The output signal of the demolator circuit and the conditional signal is connected to the Analog to Digital (ADC) system by using an arduino UNO R3 microcontroller so that the signal readings can be converted into digital form. The ADC reading results that have been converted into units of length (mm) from Arduino will be displayed on the LCD 16 x 2. Furthermore, this data will also be displayed and stored on a computer / laptop during the measurement. The overall schematic of the LVDT sensor can be seen in Figure 4 [8].

3.2. System of Land Displacement measurement

Land displacement can be observed directly in landslide prone locations and also in the form of simulations. In this study conducted in the form of simulations using a container filled with soil and the parameters are equated with the conditions in the field. The design of ground shift measurement system tools using this LVDT sensor can be seen in Figure 5.
In this simulation the soil is put into a container measuring 100 cm x 30 cm x 30 cm. The container is then tilted to the desired angle. The tilt angle variations used in this study are 40°, 45° and 50° angles. To make the movement of the soil, the soil is doused with water using a specially designed pipe so that the water can spread evenly throughout the container as shown in Figure III.6. So that the water that comes out is constant, then in this system a water pump with a water discharge of 3.76 cc/sec is used. For each variation of the slope of the container, 18000 seconds or 5 hours will be observed [8].

4. Result and Discussion

4.1. Prototype of LVDT Sensor
In this study, an LVDT sensor has been developed which will be developed into a land displacement sensor. Sensor that has been made can be seen in Figure 6.

The measurement range of this LVDT sensor is from 0 - 140 mm or 14 cm. Based on research results from landslides or landslides will occur in soil shifts up to 5 cm for a slope angle of about 45°. Based on this data, the LVDT sensor that has been made is made into a disaster mitigation system for early warning of landslides.
4.2. Measurement of Land Displacement

The angles used are 40°, 45° and 50° as shown in Figure 7. The duration of watering is 18000 seconds or about 5 hours. At the 30th minute cracks begin to occur on the ground which makes the ground shift. This shift data is read by sensors displayed via the LCD, and also stored on the laptop.

In Figure 8 we can see experimental results of soil shifting at each slope angle. This graph shows that the magnitude of the slope angle affects the magnitude of the ground shift. At an angle of 40° and 45°, there was a shift in the soil around 1800 seconds or 30 minutes after watering began. While at an angle of 50° the land shift occurred at an interval of 2000 seconds. Initially, the shifting of the ground at the largest angle of 45°, but over time the watering angle of the 50° has the greatest shift, this is influenced by the forces acting on this system, where the greater the angle of inclination, the greater the tensile force of the soil cause a shift to occur. At 18000 seconds or 5 hours the magnitude of the shift at an angle of 40°, 45°, and 50° are 5.5 mm, 27.6 mm and 28.3 mm.

Figure 7. Variation in the slope of the soil (a) 40°, (b) 45°, (c) 50°
5. Conclusion
This study obtained several conclusions, that the LVDT sensor that has been made has the smallest scale value of 0.1 mm with a measurement range of 140 mm. The Sensor can measure land displacement for mitigation system. The angle of the ground is directly proportional to the magnitude of landslides.

Acknowledgments
This research was supported by DRPM Kemenristek DIKTI. We thank our colleagues from LPPM UKI Toraja who provided insight and expertise that greatly assisted the research of this paper.

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