International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

Electric Pole Orientation Detection and Alerting System Using Laser Beam

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Abstract:
The utility poles of an electric power distribution system are frequently damaged by wind-related disasters. This study notes that the electric poles are particularly vulnerable to such disasters and the failures of the poles can cause a network-level failure leading to short- or long term power outages. To mitigate the problem, this study proposes a framework for measuring the resilience of theelectric utility poles based on the angular deflection of a pole due to the wind force. Given the existing inclination angle of a pole, the angular deflection is measured by finite element analysis using ANSYSWorkbench1 to determine the resilience area under various wind speeds. For this, the conditions of load and support for a pole, which are called boundary conditions in ANSYS, are generated. The proposed framework also includes an approach to cost–benefit analysis that compares different strategies for corrective action. The results of the case study in which the framework was applied show that the proposed framework can be effectively utilized by electric power distribution companies to increase the resilience of their systems.

KEYWORDS: ANSYS

I.INTRODUCTION

The power distribution system is one of the most vital components of modern society. But this system is vulnerable to disasters caused by wind-related events such as tornados and hurricanes, which frequently incurs power outages. Extreme weather events and climate change are the two most significant causes of power outages in various parts of the world (Mukherjee et al. 2018). As the intensity of the two causes has increased, power outages due to these causes have also significantly increased (Kenward and Raja 2014). Among the various components of the power distribution system, the poles are frequently damaged by wind-related disasters, which ultimately leads to hours of power outages that extend for days or even weeks, depending on the intensity of a particular disaster. For example, Hurricane Harvey seriously damaged approximately 5000 power distribution poles in Texas in 2017 (AEP Texas 2017). As the severity and frequency of natural hazard-induced disasters are increasing year by year (NOAA 2017), it is imperative for power utility companies to develop resilient utility poles for the electric power distribution network.

There are various factors causing damages to a pole, including the trees and branches located nearby power lines and poles, structural deterioration of a pole, flooding, storm surges, debris produced by winds, and so on (Pellicane and Franco 1994; Oudjene and Khelifa 2009; Schmidt and Kaliske 2009; Ryan et al. 2014). The present study notes that inclined poles become more susceptible to these factors during a wind-related disaster. Therefore, the goal of this study is to develop a practical methodology that can help to increase the resilience of power distribution poles threatened by wind-related disasters. The research objectives of this study are: (1) to create a photogrammetry- based method for evaluating the condition of a pole based on its angle of inclination; (2) to determine the resilience areas based on the condition of a pole; (3) to develop a damage prediction method using finite element analysis; and (4) to conduct a cost–benefit analysis of resilience improvement strategies. The results of our research indicate that the proposed methodology is useful in assessing the health condition of each pole and in evaluating strategies for preventive maintenance of poles. This article is organized as follows. Section 2 presents a summary of the literature relevant to the resilience of power distribution systems, pole failures.

II.PROBLEM STATEMENT

The aim of this study is to develop a practical methodology that can help to increase the resilience of power distribution poles threatened by wind related disasters.

III. LITERATUREREVIEW

This section summarizes the literature review in terms of three subject areas: resilience of power distribution systems, failures of the poles of electrical distribution system, and cost benefit analysis.

As the severity and frequency of natural hazard-induced disasters increase year by year (NOAA 2017), utility companies are very keen to develop resilient power distribution systems. An electric pole-based resilience assessment can establish a strong base for pre storm planning. The literature shows a variety of definitions of resilience is ‘‘the ability of an entity or system to return to normal condition after the occurrence of an event that disrupts its state.’’ Similarly, Nan and Sansavini (2017, p. 36) define resilience capability as ‘‘the ability of the system to withstand a change or a disruptive event by reducing the initial negative impacts, by adapting itself to them and by recovering from them’’.

Several studies have been conducted on the failure of electric poles in the power distribution system. Shafieezadehet al. (2013) found that electric poles often fail due to a wind load greater than the flexural capacity of a pole. Han (2008) examined two mechanisms that cause the failure of poles—flexural failure due to the wind load and foundation failure. A structural analysis involving wind loads and the probabilities of failure has been conducted in the Caribbean Disaster Mitigation Project (1996). In this project, the wooden pole was assumed to be a cantilever beam that will fail if the bending stress exceeds the modulus rupture of a pole. Tara’s et al. (2004) argued that the strength of a pole is subject to decay over time and a pole may fail due to lateral bending. United States utility companies have struggled to strike a balance between over- and under-preparation because they lack a rigorous methodology with which to estimate the damage caused by hurricane winds (Guikema et al. 2010). Various methods have been proposed by researchers to increase the reliability of power distribution systems under wind-related disasters and to decrease the time required to restore damaged systems. These efforts can be largely divided into two groups: predictive models and storm hardening models (Salman et al. 2015; Wanik et al. 2015). Predictive models are popular because they can support pre-event activities for better resource allocations.

Some of the notable previous works that proposed predictive models are:

- Guikema et al. (2010) developed a model to predict the number of utility poles that need to be replaced based on wind-related damage data from previous storms by applying regression analysis and data-mining techniques.
- Salman et al. (2015) applied fragility analysis and Monte Carlo simulation to determine the probability of pole failure with varying wind speeds from which they proposed targeted hardening strategies based on an index of important components. They considered the whole system rather than an individual pole.
- Ouyang and Duenas-Osorio (2014) introduced a component fragility model to quantify the resilience of the electric power system in which poles are considered to estimate the fragility of the entire distribution system.
- Shafieezadeh et al. (2013) developed a fragility curve of wooden poles based on the moment capacity of the pole and the moment demand placed on those poles by wind loads. However, they did not consider the deflection and deformation of a pole incurred by wind loads.
- Darestani et al. (2016) proposed a boundary model to capture the boundary effects of adjacent wooden poles in response to wind-induced forces. They used a time-dependent decay model and a probabilistic wind model to perform a Monte Carlo simulation to determine the probability of pole failure. In contrast to Darestani and his colleagues, the present study is focused on the evaluation of the condition of individual poles. In our study, the angular deflection of a pole due to wind force is considered as damage to the pole, and a damage prediction model is proposed to predict pole failure based on its angular deflection.

The poles of an electric power distribution network in wind-prone regions suffer from various types of damage. Evaluation of the condition of poles is thus imperative. The ability to predict potential damage to poles before the occurrence of a wind-related disaster enables decision makers to plan preventive maintenance operations in a timely manner and to allocate resources effectively. To this end, it is necessary to understand the physical properties of a pole. The following briefly summarizes the material properties and geometry of the utility poles of an electrical power distribution network. Poles are made of various materials, such as wood, steel, concrete, fibre reinforced polymers, laminated wood, and so on. Wood is the most commonly used in the United States for the poles of a distribution system because of its cost-effectiveness and functionality (Daugherty 1998; Crosby 2011). In particular, the southern yellow pine is the most widely used in North America (Dunn and Young2004); for this reason, it was selected for examination in this study. Modelling a wooden pole is complex due to the natural imperfections of wood, which may affect the expected behaviour of the material. It is difficult to determine the mechanical properties of a wooden pole because of its greatly variant elastic behaviour (Dias et al. 2007). The mechanical properties of southern yellow pine are different for each orthotropic direction and variant under tension and compression. Under compression, it shows plastic behaviour, which can be described by connecting the elastic–plastic law. On the other hand, it is likely to show brittle behaviour under tension (Federal Highway Administration2007).The geometry of a pole is an important parameter for designing and determining the angular deflection of that pole from its original position due to wind-induced forces. Utility companies in the United States commonly use two methods to design their poles—the National Electric Safety Code (NESC 2002) and the standards of American Society of Civil Engineers (ASCE 2006a). Meanwhile, the specifications and dimensions of poles are established by the standard number, ANSI O5.1, of the American National Standards Institute (ANSI 2017). ASCE (2006b) provides minimum design loads for buildings and other structures—a standard that was used as a reference for wind load provision in this study. The pole height was assumed to be 12.19 m with a taper ratio of 0.263/0.154 (Diagnd/Diatop, m/m). The top of a pole is normally connected with two or more electric cables, which exert tensional forces. However, for simplicity, the cables connecting poles were not taken into consideration because the present study aims to explain the direct impact of wind force on poles. For a comprehensive picture, it will eventually be necessary to examine the effect of tensile forces exerted on poles by the connecting cables. In the present study, the top of a pole was assumed to be free of support whereas the bottom of a pole was considered to have fixed support. Wind force was considered to be uniformly distributed on the pole while the gravitational force.

IV.PROPOSED SYSTEM

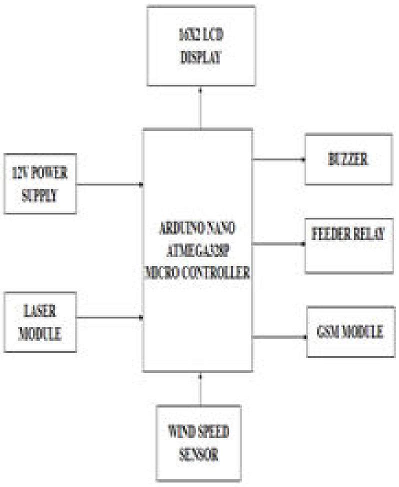

Fig:Block Diagram

The Arduino Nano ATMEGA328P microcontroller placed at the center of the block diagram as shown in above figure.The laser module consists of laser beam emitter and laser receiver.In this project we use 12V power supply.When laser beam emitter is connected at one side of pole and laser receiver is connected at opposite pole.When any one of pole gets titled and check which pole is bend,then laser receiver will sends a output signal to the microcontroller and this microcontroller sends a message to the authorised person through GSM module.The result will displayed in the LCD screen and wind speed sensor is used to find the speed of the wind.If wind speed exceeds the preset value this gives a message to the authorised person through GSM and the speed will be displayed in the LCD screen.The person can trip the supply of that location through sms,by manual operation or low voltage relay.

V. METHODOLOGY

In this project we have chosen some methods to predict pole orientation and also minimize the power loss due to wind effects. The methods are as follows

- Procurement of hardware components to measure the pole orientation.
- Pole structure to demonstrate the proto model.
- Calculating the pole angle with respect to ground. And mounting the laser beam emitter and receiver at each pole.
- Wind speed measuring device and mounting on the pole.

- Connecting all circuit components and programming the microcontroller.
- Trouble shooting and get the expected results.

VI. FLOW CHART

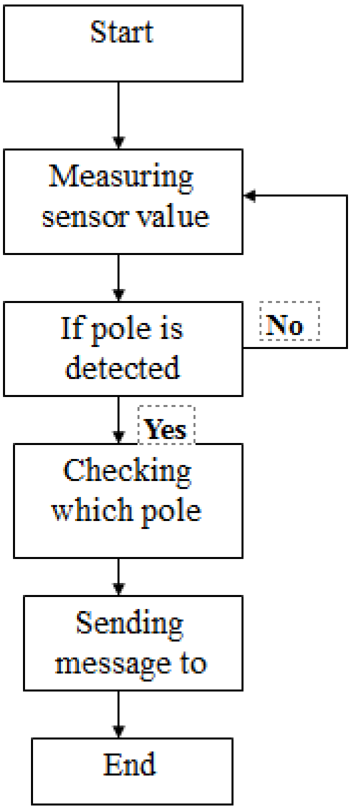

Fig:Flow Chart

VII. CONCLUSION

Electric poles are one of the critical components of the electrical power distribution network, because the poles are frequently damaged by the wind related disasters. We believe that evaluation of pole condition and estimation of potential damage before and after the occurrence of disasters will help decision makers increase their capacity to prepare for and recovery from wind-related disasters. A framework for predicting pole damages is proposed in this study; the ultimate purpose of the framework is to determine the resilience area of a pole for pre and post-disaster situations. The methodology also can enable utility companies to estimate the amount of time required to fix damaged poles and effectively allocate resources to critical preventive maintenance and recovery operations.

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