UNIVERSITI PUTRA MALAYSIA

THE DEVELOPMENT OF A PORTABLE FIBER OPTIC BASED LIGHTNING DETECTOR SYSTEM

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By

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This project is to demonstrate the development of a fiber optic based lightning detector system using a programmable logic controller. Basically, the project is developed to collect the lightning profiles. It is able to detect the lightning flash and store the lightning data as well as the time of occurrences into a programmable logic controller. It is capable of detecting the cloud to ground lightning, intercloud lightning, intracloud lightning and others. The data could be retrieved and viewed through the personal computer (PC) as desired.

Two sections are taken into consideration for the whole system design. These sections are hardware and software design. The system hardware consists of 4 main parts. They include a sensing unit, a data transmission unit, a signal conditioning unit and a data storage unit. Most of the hardware involves circuitry designs. Based on the designs, printed circuit boards (PCBs) are constructed by using the electronics application software (PROTEL). On the other hand, the system software design is a

program, which is written in ladder logic programming. The software is designed for the purpose of handling and organizing the incoming lightning data into PLC or data logger.

This project was tested in 2 modes. One of the modes is the testing of the individual parts of the project. The other mode is the testing of the integration of all parts of the project, which is including software and hardware system. In individual part testing, each of the circuits was tested separately. The voltage is fed manually into the circuits for testing their performance and functionality. The software design is tested without integrating with the hardware system. In the integration testing, the hardware and the software have been combined or integrated. The project is tested and justified under the real condition of detecting lightning. Both of the testing has proven that the invention is working properly and successfully.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN SISTEM PENGESANAN KILAT MUDAH-ALIH BERDASARKAN FIBER OPTIK

Oleh

KOH HONG KEONG @ GOH HONG KEONG

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Pengerusi: **Dr Ishak Bin Aris**

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Projek ini dilaksanakan untuk menunjukkan pembangunan sistem pengesanan kilat mudah-alih berdasarkan fiber optik dengan mengunakan pengawal logik boleh diaturcara (PLC). Secara asasnya, projek ini digunakan untuk mengumpulkan maklumat-maklumat kilat. Sistem ini berkebolehan untuk mengesan setiap kejadian kilat dan menyimpan data-data kilat dengan masa kejadian masing masing ke dalam pengawal logik boleh diaturcara. Ia berkebolehan untuk mengesan jenis kilat dari awan ke bumi, kilat antara awan, kilat dari awan ke udara dan sebagainya. Data-data tersebut boleh dikeluarkan dan diperhatikan melalui komputer ketika diperlukan.

Dua bahagian telah diambilkira dalam rekabentuk keseluruhan sistem ini. Bahagian-bahagian tersebut adalah rekabentuk perkakasan dan perisian. Sistem perkakasan mengandungi 4 unit yang penting yang terdiri daripada unit pengesanan, unit penyebaran data, unit penyelenggaraan isyarat dan unit penyimpanan data. Kebanyakan sistem perkakasan meliputi rekaan litar-litar. Berdasarkan rekaan

tersebut, papan litar (PCB) telah dihasilkan dengan menggunakan perisian elektronik tertentu (PROTEL). Sementara itu, sistem perisian merupakan satu rekaan program yang dituliskan dalam bentuk pengaturacaraan logik tangga. Sistem perisian ini diciptakan dengan tujuan untuk memanipulasikan data-data kilat ke dalam pengawal logik boleh diaturcara.

Projek ini telah diuji melalui 2 mod yang berlainan. Satu daripadanya ialah pengujian komponen-komponen projek secara individu. Mod yang satu lagi ialah pengujian gabungan semua komponen-komponen projek yang melibatkan sistem perisian and sistem perkakasan. Dalam pengujian komponen-komponen projek secara individu, setiap litar telah diuiji secara berasingan. Voltan dialirkan ke dalam litar-litar supaya dapat menguji kebolehan dan keberkesanan litar masing-masing. Sistem perisian pula diuji dalam keadaan tanpa digabungkan dengan sistem perkakasan. Sementara itu, dalam pengujian secara gabungan, sistem perkakasan dan sistem perisian telah digabungkan. Projek ini diuji and diperiksa secara praktikal untuk megesan kilat. Kedua-kedua pengujian tersebut telah membuktikan bahawa ciptaan ini berfungsi dengan sempurna dan berjaya.

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I certify that an Examination Committee met on 17th May 2002 to conduct the final examination of Koh Hong Keong @ Goh Hong Keong on his Master of Science thesis entitled "The Development of a Portable Fiber Optic Based Lightning Detector System" in accordance Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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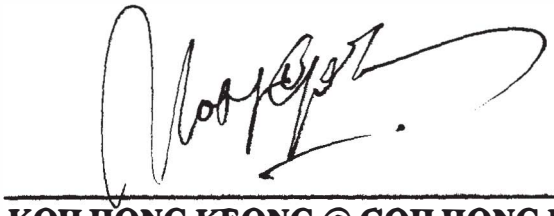
I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



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LIST OF ABBREVIATIONS

AC	Alternative Current
AM	Amplitude Modulation
ADC	Analog to Digital Converter
APD	Avalanche Photodiode
COM	Common
CRT	Cathode-ray Tube
DC	Direct Current
ELED	Edge Light Emitting Diode
EMI	Electromagnetic Interference
FET	Field-effect Transistor
FM	Frequency Modulation
I/O	Input and Output
LDS	Lightning Detector System
LED	Light Emitting Diode
LSB	Least Significant Bit
MSB	Most Significant Bit
NA	Numerical Aperture
Op-amp	Operational Amplifier
PC	Personal Computer
PCB	Printed Circuit Board
PD	Photodiode
PLC	Programmable Logic Controller
PIN	Positive-intrinsic-negative

PAM	Pulse Amplitude Modulation
PPM	Pulse Position Modulation
SLED	Surface Light Emitting Diode
TNRD	Tenaga Nasional Research and Development

CHAPTER 1

INTRODUCTION

1.1 Introduction of Project

Lightning is one of the most powerful and ever-mysterious forces on earth and it is one of the leading weather-related causes of deaths and injuries. According to British Standard 6651, lightning is a natural hazard, being the discharge of static electricity generated in parts, called 'cells', of storm clouds. Part of the lightning victims die and most of them suffer serious long term after effects. Psychological effects of lightning incidents include memory loss, depression, headaches, confusion and inability to work.

Lightning causes damages to building and electrical or electronic equipment. It may occur from a strike point a mile away and propagate in the power system to the user's facility. Even where no obvious damage has occurred, the life of electronic equipment can be significantly reduced following a lightning surge. Due to this factor, the equipment failure may not happen immediately but may take months to happen.

Since the lightning present a number of serious threats; the needed of a lightning detection system is necessary to collect the lightning profile. From the profile, some of the characteristic of lightning can be analyzed. The frequency of the lightning flashes and the time of occurrences will be recorded. Based on the data obtained from this detection system, a suitable lightning protection system could be installed on the new protection area. By doing this, the cost to install the suitable lightning protection system in a particular new building can be reduced.

A portable lightning detector system using both fiber optic and programmable logic controller approaches is proposed to solve the problem mentioned above. This system is capable of detecting the flashes of lightning and recording the time and date when the lightning occurs. The fiber optic is used in the design of the proposed system as its transmission channel to transmit the data from the optical transmitter circuit to the optical receiver circuit. The programmable logic controller (PLC) is applied to collect and store the data with the date and time of the lightning occurrences. This data can be viewed or retrieved from the personal computer (PC) either using the online method or the offline method.

Based on the data, some of characteristics of lightning in certain area can be analyzed. The author will get to know the information of the number of the lightning day and the number of the lightning flash. On the other hand, the times and dates of the lightning's occurrences will be recorded for further lightning analysis. According to the data, the author can also predict the distance that lightning occur whether it occur far away or near to the measuring center. The system is portable and it can be brought to anyway easily for the lightning researches purpose.

This project system consists of hardware and software as shown in Figure 1.1. The hardware design is divided into 5 main parts those are sensing unit, data transmission unit, signal conditioning unit, data storage unit and data retrieving unit. On the other hand, the software design is a program written in ladder logic programming. It is applied to handle and manipulate the incoming lightning data into the PLC. The data will be arranged and stored systematically according to their time and date of occurrences. The author or user can see the data through the PC. This can be done by

just connecting the PLC to the PC with the use of RS422 connection system. FPWIN GR is application software that is applied to program the PLC and retrieve the data from the PLC.

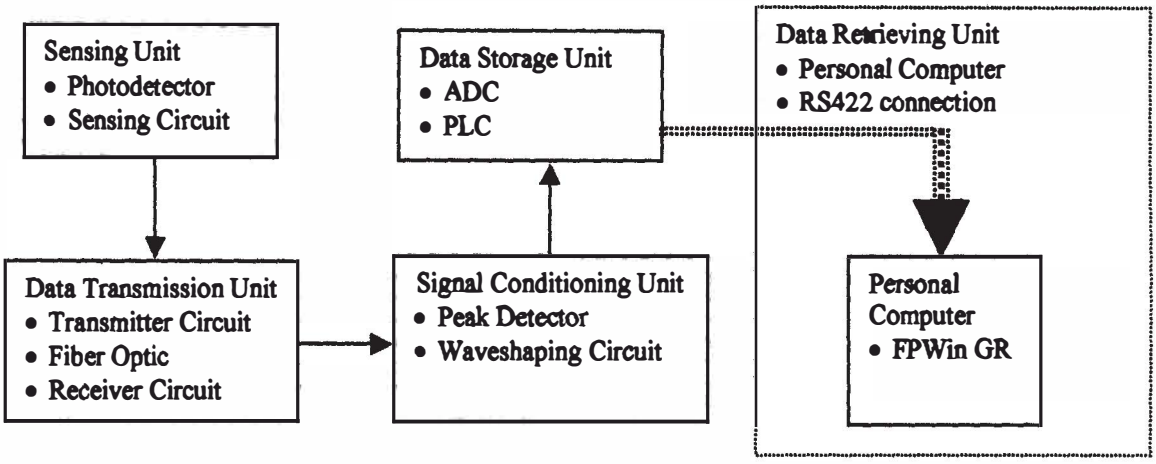

Figure 1.1: Project system configuration

1.2 Aim of Project

The aim of this project is to develop a portable lightning detector system that could be used to detect lightning flashes. This invention is able to collect and store the occurrence of lightning flashes with the time and date. The transmission system of this project is developed based on the fiber optic technology.

1.3 Objectives

The following points are the objectives derived from this project:

i. To develop a system with the ability to collect and store the data of lightning flashes.

ii. To develop a sensing unit, which is able to detect the flash of lightning.

iii. To develop a fiber optic based data transmission system to transmit the data of lightning flashes.

iv. To develop a signal conditioning unit for transforming the sinusoidal signal to DC signal and attenuating the ripple voltage of the system.

v. To develop a data storage unit to store the lightning flash data and recording the time and date of the occurrences of the lightning flash.

vi. To develop an analog to digital converter (ADC) system to convert the analog signal to digital signal that is useful for PLC operation.

vii To develop a ladder logic program to control the programmable logic controller in handling and manipulating the incoming digital data from ADC.

viii. To construct PCBs for the circuits design of the project.

1.4 Thesis Layout

This thesis comprising 5 chapters those are introduction, literature review, design methodology, result and discussion and conclusion. The first chapter gives the introduction to the project. Chapter 2 reviews literature on some features of lightning, effects of lightning, lightning protection, fiber optic applications, light emitting diodes, photodetector and programmable logic controller. Chapter 3 is the Design Methodology to describe some techniques and methods in designing the hardware and software system of the project. The hardware design including sensing unit, data transmission unit, signal conditioning unit, data storage unit ADC tester and power supply circuit. On the other hand, software is designed by using ladder logic programming for handling the incoming lightning data to the PLC. Chapter 4 discusses the circuits testing results, real time measurements, circuits performance and the discussions of some precaution steps during the implementation of the project. The last chapter explains the conclusion and the suggestions of improvement of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 An Introduction to Lightning

In general, lightning is a natural phenomenon that is of great concern to mankind and industry because of the detrimental impact of human safety, hazard and equipment failures due to AC main power conducting electrical transients (Ahmad, 1996).

The scientific study of lightning began about 250 years ago. In 1752, Benjamin Franklin demonstrated the electric nature of lightning by executing a famous but exceptionally hazardous experiment. Benjamin Franklin tied a metal key to the end of a kite string and flew the kite in a thunderstorm. The electric charge in the cloud raised the voltage of the kite string. This high voltage caused a spark to jump from the key to grounded objects, showing that the cloud was electrified. Fatalities resulted from attempts to reproduce a number of Franklin's experiments, and he was indeed fortunate that he was not among them (Stenhoff, 1999).

Beginning with Benjamin Franklin's work and for many years thereafter, lightning protection design was primarily concerned with the protection of buildings and structures. Tall-earthed rods on the top of buildings were found to provide protection from direct strikes in that lightning struck the rods instead of the buildings and was conducted harmlessly to earth. Franklin was the first to recognize that the height was an important factor in the design of lightning protection system (Golde, 1967).