

**FIBER OPTIC AS ELECTRIC CURRENT SENSOR**

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*To my parents  
Brothers and Sisters  
And all fellow friends*

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## ABSTRACT

Nowadays, fiber optic is used broadly in communication area because it is proven to be more efficient than the copper cable. The special advantage of optical fiber is its immunity to electromagnetic interference. Furthermore, the price is now getting much cheaper. In other areas, fiber optic is also widely used. The aim of this project is to research on the use of fiber optic as a current sensor. The fiber optic will be coil around a current carrying conductor. The light that injected into the fiber optic will be polarized because the existence of electric current in the conductor. The measurement of the current will be based on the polarization of the light. By developing a relationship between the current flow and light polarization, the optical fiber can be used as a current sensor.

## ABSTRAK

Pada masa sekarang, gentian optik digunakan secara meluas dalam bidang telekomunikasi kerana keberkesannya yang lebih baik dari kuprum. Gentian optic terbukti tidak dapat dipengaruhi oleh aruhan magnet. Harga gentian optik menjadi semakin murah. Untuk kegunaan lain, terdapat juga penggunaan gentian optik sebagai alat pengesan. Tujuan projek ini dijalankan adalah untuk mencipta satu alat penguji arus elektrik yang menggunakan gentian optik. Dengan kelebihan yang ada pada gentian optik berbanding alatan lazim pada hari ini, adalah diharapkan alat ini dapat menguji arus yang dihasilkan oleh kilat. Daripada ujikaji yang dijalankan di dalam projek ini, telah terbukti bahawa pengutuban cahaya sememangnya dipengaruhi arus elektrik yang mengalir melalui bahan konduktor. Pengwujudan perhubungan antara pengutuban cahaya yang disebabkan oleh pengaliran arus menunjukkan gentian optik boleh digunakan untuk pengukuran arus.



<b>CHAPTER</b>	<b>CONTENT TITLE</b>	<b>PAGE</b>
	<b>PROJECT TITLE</b>	i
	<b>STATEMENT OF VERIFICATION</b>	ii
	<b>DEDICATION</b>	v
	<b>ACKNOWLEDGEMENT</b>	vi
	<b>ABSTRACT</b>	vii
	<b>ABSTRAK</b>	viii
	<b>CONTENT</b>	ix
	<b>LIST OF TABLE</b>	xii
	<b>LIST OF FIGURE</b>	xiii
<b>1</b>	<b>INTRODUCTION</b>	
1.1	Project Introduction	1
1.2	Problem Objective	2
1.3	Problem Statement	3
1.4	Project Scope	5
1.5	Project Methodology	6
1.5.1	Phase 1: Project Planning	6
1.5.2	Phase 2: Literature Review	7
1.5.3	Phase 3: Hardware Realization	7
1.5.4	Phase 4: Finishing	7
1.6	Thesis Overview	8
<b>2</b>	<b>LITERATURE REVIEW</b>	
2.1	Characteristic of Fiber Optic	11
2.2	Structure of Fiber Optic	12
2.3	Types of Fiber Optic	13
2.3.1	Single Mode Fiber Optic	13
2.3.2	Multi Mode Fiber Optic	13

2.4	Characteristic of Fiber Optic	14
2.4.1	Light Sources	15
2.4.1.1	Light Emitting Diode	15
2.4.1.2	Laser	17
2.5	Lightning Characteristic	19
2.6	Measurement of Current in Optical Fiber	21
2.7	Faraday Effect	22
2.8	Verdet Constant	22
2.9	Faraday Rotator Material	23
2.9.1	Optical Fiber	24
2.9.2	Bulk Glass	24
2.9.3	Ferrimagnetic Material	25
2.10	Photodetectors	25
2.10.1	Introduction	25
2.10.2	Types of Photodetectors	27
2.10.2.1	PIN Photodiode	27
2.10.2.2	Avalanche Photodiode	28
2.11	Fiber Cables	30
2.11.1	Step-Index Fiber	31
2.11.2	Graded-Index Fiber	33
<b>3</b>	<b>PROJECT METHODOLOGY</b>	
3.1	Project Introduction	35
3.2	Project Flowchart	36
3.3	Methods and Approaches	38
3.4	Measurement Method	39
3.5	Project Measurement	39
3.6	Main Material	39
<b>4</b>	<b>RESULT AND DISCUSSION</b>	
4.1	Result and Discussion	44
4.2	Research of the Polarization of the Light	44
4.3	Data Analysis	45

<b>5</b>	<b>CONCLUSION AND SUGGESTION</b>	
5.1	Conclusion	47
5.2	Suggestion	48
	<b>REFERENCES</b>	<b>50</b>

## LIST OF TABLE

No.	TITLE	PAGE
4.3.1	Analysis In Term Of Input And Output Voltage	45

## LIST OF FIGURE

<b>NUMBER</b>	<b>ITEM</b>	<b>PAGES</b>
2.1	LED Light Sources	15
2.2	Laser Light Sources	18
2.3	PIN Photodiode Operation	27
2.4	Propagation of Light In Step Index Fiber	31
2.5	Construction of Graded Index Fiber	33
3.1	Working Flowchart	37
3.2	Light Source LED 850nm	40
3.2	Optic power meter	41
3.3	Direct Current Sources	41
4.1	Graph of output voltage versus input voltage	46

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Project Introduction**

This project is to design an electric current measurement device by using optical fiber as a sensing element. This device expected can measure very high current such as in lightning strike. Nowadays, although there are many current measurement devices, just a few of them are designated to measure very high electric current value and none of these devices were based on optical fiber as the sensing element. The optical fiber, already known of its wide use in telecommunication system as a data transmission medium has many other uses. Optical fibers are not just used as transmission medium but also as sensing device in sensors and alarm system.

Optical fiber current sensor has many advantages as compare to the conventional current measurement device. Optical fiber has higher sensitivity compare to other conventional current measurement device and it can give more accurate measurement.

## 1.2 Project Objective

Basically, the main objective of this project is to study and do research work in designing an electric current measurement device by using optical fiber. Optical fiber has many advantages when it is utilized for the purpose of detecting electric current. The primary advantages are:

- Reduced weight : the thickness of fiber optic even though it was coated is very thin and very light
- Wide measurement range: it can cater high current measurement
- Immunity against inductive interference: fiber is a dielectric material. Unlike metal, fibers does not act like antennas to pick up RFI (radio frequency interference), EMI (electromagnetic interference) or even EMP (electromagnetic pulse)

There are also several secondary advantages by using FO as the sensing element:

- Greater safety: in FO, only light propagate, not electric. Even if FO damaged, it will not produce spark. Also, in FO, is impossible to have short circuit.
- Longer life span: FO predicted can stand for 20 to 50 years compare to copper.

- Environmental stability: only extreme cold ( $-20^{\circ}\text{C}$  to  $-40^{\circ}\text{C}$ ) cause increase in attenuation. Water has no effect at all.
- Common natural resources: FO is made of Silica (sand) rather than hard to find sources such as copper.

With these advantages of fiber optic current sensors, the readings obtained can be more accurate because it immune to interference. This fiber optic current sensor has less probability to be damaged by the excessive current flow but nature of its physical properties.

### **1.3 Problem Statement**

There are many attempts to measure electric current by using optical techniques including by using fiber optic as the sensing element. Many theoretical thoughts were proposed to improve fiber optic to be able to use as the measurement material.

With the recent rapid growth on higher voltage in electric system, the difficulty of isolation has contributed to high rise in cost for inductive current transformer. Therefore, fiber optic can be more preferable because fiber optics is very good isolator and immune to electromagnetic interference.

Although many current measurement devices were used to measure the current value, only few of them could measure very high current value such as the current



caused by lightning. The current measurement devices for high current measurement nowadays are still very inefficient because they are mainly used for measurement based on electrical signal and has a limited measurement range. Here, the fiber optic can encounter this weakness because of the followings:

- The fiber optic current sensor have less probability to be damaged by unexpected over current surge such as lightning stroke.
- Fiber optic current sensor has immunity against electromagnetic interference because the magnetic field caused by high current value is directly converted into an optical signal.

Even fiber optics have the above advantages, there are other challenges when using fiber optics as the sensing elements. Many researches before have failed to meet the criteria to use fiber optic as the sensing elements. The main problem here is due to the instability of fiber optic as the sensing element.

## 1.4 Project Scope

The first thing to focus on this project is to choose the right material as a sensing element. The sensing element can be based on optical crystal or optical fibers. As for the sensing element, three materials can be taken into consideration. The three materials are:

- Optical Fiber
- Bulk Glass
- Ferromagnetic Material

As for the sensing element for this project, the optical fiber was chosen because this material can be obtained from UTeM as compared to the bulk glass and ferromagnetic material which were not easily available in the market. The optical fiber will be discussed later in this report.

Each measurement device has its own unique calculations and parameters to determine the value of thing that measured. As for the fiber optic current sensor, the measurement will be based on the polarization of the plane of the light. To put it simply, the induced magnetic field that was created from the current flow will polarize the light in the optical fiber. The value of the current will be determined from there.

There are three general parts in this research to determine the electric current from the light propagate in the fiber optic. First is the light source, second is the circuit that carries electric current and third is the photodetector used to convert the light back to electric to measure the output current. The details of the experiment will be discussed later in this report.

## **1.5 Project Methodology**

### **1.5.1 Phase 1: Project Planning**

As in the schedule for the Bachelor Degree Project, it was necessary to meet the project supervisor at once a week to report the progress of the project and also to get the comment and feedback on ideas to realize this project. A lot of information was obtained from journals, thesis and books. These knowledge acquired were understood and brought to the supervisor to discuss on their relevance and significant towards the project. Along the process, several experiments were conducted to prove the theory is right.

### 1.5.2 Phase 2: Literature Review

More ideas related to the project were mainly obtained from the journals and catalogues. The literature review was mostly conducted while in PSM 1. The type of optical fiber chosen for the project was based on the specifications found in the books and discussion with supervisor and lecturers.

### 1.5.3 Phase 3: Hardware Realization

For hardware realization, the circuit was tested for high current measurement and the values obtained were compared with the values obtained from the conventional current measurement devices. The pros and cons in using fiber optic as current measurement device will be discussed.

### 1.5.4 Phase 4: Finishing

After the hardware was completed, measurements taken and analyzed, it was time to prepare the power point slides and several other materials for presentation on the achievement and outcome of the project. After the presentation, further improvements were made as a result from the comments and recommendations of the panel. The final task is to prepare this thesis as a documented evidence for the completion of the PSM II project.

## 1.6 Thesis Overview

In Chapter I, the summary of each chapter in this report was discussed. Chapter I discusses mainly on the introduction and background of this project. Topics that are included in this chapter are project introduction, objectives of the project, problem statement of why this project was undertaken, project scope and project methodology. Chapter I also consists of the summary of this report.

Chapter II discusses about the literature reviews that were carried out through the period this project was being done. The literature review of this project focuses on the type of optical fibers, their applications, the principles and techniques in using optical fiber and how to measure current based on polarization of light.

In Chapter III, the methodology of this project is presented. The methodology includes the procedures carried for data collection and data analysis. The chapter also includes the flowchart of the project methodology.

Results and discussions were deliberated in chapter IV. All the results and analysis, the testing and re-testing, the simulated and actual responses would be discussed in this chapter to determine whether the main objectives of the project are achieved or not.

Finally, in chapter V, it consists of the conclusion. This chapter also contains the recommendations and suggestions for further development and enhancement. This is important to see whether the project is viable and has practical and commercial significant the industry.

## **CHAPTER 2**

### **LITERATURE REVIEW**

There are many different variations of current measurement devices available nowadays. Generally, they can be classified into two major categories. The first category is the direct electric current measurement method. This type measures current directly to its source. The source is the conductor that the current flowing in it. The second category is the one that measures the current based on the induced magnetic field produced by the flow of current along a conductor. The first category mentioned earlier is not suitable to measure high current values. That is because it not safe and the device will have a very high probability of being damaged by excessive flow of current. When it comes to measuring of high current values, the second category or the indirect method is more preferable.

The fiber optic is well known in its effectiveness as a signal transmission medium. It can send data more accurately than by using copper as the medium of transmission. Fiber optic is also widely uses as sensing devices. But, the usage of the

fiber optic in current measurements especially high current, is still in its preliminary stage. The effectiveness of fiber optic as measurement device could be more effective than the conventional measurement device used nowadays. The advantages and details about fiber optic will be discussed in details in this chapter.

## **2.1 Characteristic of Fiber Optic**

Fiber optic as we know now is widely used as a transmission medium in telecommunication. But fiber optic has one behavior which enables it to be used in current measurement. What enable fiber optic to measure current is Magneto Optic phenomena. This phenomena happens when optical properties of certain material is affected by the magnetic field from the environment or it own magnetization. Faraday Effect plays the important role here. This occurs when linearly polarized light propagates through a material exposed to a magnetic field aligned parallel to the direction of propagation of the light. Fiber optic is suitable to measure high current value such as lightning because it has three major advantages over other current measurement device. In measuring lightning current, a device must have broad frequency spectrum, wide measurement range and has the immunity against electromagnetic interference (EMI). The fiber optic current sensor are not easily damaged by the unexpected surge that caused by the lightning stroke. The fiber optic immunity against EMI has no influence on the magnetic field that is caused by the current flowing directly and being converted into optical signal.