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Design a system to transfer alternating current in optical fiber using a light-emitting diode

project

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SUPERVISOR CERTIFICATE

I certify that the project entitled "Design a system to transfer alternating current in optical fiber using a light-emitting diode" was prepared under my supervision in the Laser and Optoelectronics Engineering Department \ University of Technology, as partial fulfillment of the requirement of the B.Sc. Degree in Optoelectronics Engineering.

Signature:

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Date:

DEDICATION

We dedicate this project to God Almighty our creator, our strong pillar, source of inspiration, wisdom, knowledge, and understanding. He has been the source of my strength throughout this program and on His wings only have we soared.

We also dedicate this work to our parents who encouraged us along the way and made sure to encourage us on whatever is necessary to finish what we started, God bless you.

We also dedicate our sincere thanks to the greats of the golden age

The master of optics: Al-Hasan bin Al-Haytham.

The master of mathematics: Muhammad ibn Musa al-Khwarizmi.

The master of electronics and communications: Nikola Tesla.

The door of the City of Knowledge, Imam Ali (peace be upon him)

ACKNOWLEDGMENTS

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Abstract

This project aims to design, test, and measure a three phase alternating current circuit to transmit optical signal through a 10m plastic optical fiber. Three light emitting diodes (LEDs) were used with wavelengths: 450nm, 540nm, and 630nm based on direct modulation. At each stage, the power level was measured at each phase wavelengths before and after the modulation process. The output power of each phase and wavelength was measured using optical power meter. Further, different parameters were to examine the circuit such as the voltage difference of the alternating current.

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List of Abbreviations

LPT	Laser power transmission
WPT	WIRELESS power transfer
CPT	capacitive power transfer
IPT	inductive power transfer
MPT	microwave power transfer
EV	electric vehicles
UAVs	unmanned aerial vehicles
HILPB	high-intensity laser power beam
PV	photovoltaic
LDR	Light Dependent Resistor

CHAPTER ONE

INTRODUCTION

1.1. Overview

Laser power transmission (LPT) is one of the most promising technologies in the long-range wireless power transfer field. LPT research has been driven by the desire to remotely power unmanned aerial vehicles (UAVs), satellites, and other mobile electric facilities. However, the low overall efficiency is the main issue that limits the implement of a high-intensity laser power beam (HILPB) system. As seen from the contemporary understanding of the efficiency of laser power transmission channels, the efficiencies of laser and (PV) array are the main limiting factors to the HILPB system from the perspective of power conversion. Thus, a comprehensive overview of LPT technology is presented from the point of efficiency optimization view in this paper. First, the basic principles of laser power transmission are briefly summarized. Then, a survey of the efficiency optimization methods for the HILPB system with regard to the laser and PV technologies is provided in detail. Additionally, the open issues and challenges in implementing the LPT technology are discussed [1].

WIRELESS power transfer (WPT) is the technology that electrical energy is transmitted from a power source to an electrical load without any electrical or physical connections. Compared to traditional power transfer with a cord, wireless power transfer introduces many benefits such as better operational flexibility, user-friendliness, and product durability. Therefore, WPT technology is ideal in applications where conventional conduction wires are prohibitively inconvenient, expensive, hazardous, or impossible [1]. Nowadays, WPT technology is attracting more and more attention and evolving from theories toward commercial products, from low-power smartphones to high-power electric vehicles, and the wireless-powered products will come to a 15 billion market by 2020 . The development of WPT technology is advancing toward two major directions, i.e., near-field techniques, which have a typical transmission distance from a few millimeters to a few meters, and far-field techniques, where the coverage is greater or equal to a typical personal area network [2].

The former consists of two techniques: capacitive power transfer (CPT), and inductive power transfer (IPT) , while the latter can be further sorted into microwave power transfer (MPT) and laser power transfer LPT [3]. The key advantages of CPT are high power transfer up to several kilowatts, Transfer power through metal objects without generating significant eddy currents losses, Use metal plates to transfer power to reduce cost, are Suitable for small size applications, and can be used in large size applications such as EV. The potential disadvantages of CPT are limited efficiency at the range of 70%-80% but it can reach 90%in some applications, Short transmission distance which is usually within the hundred of mm range, The challenge comes from the conflict among the transfer distance and power as well as the capacitance value. The advantages of IPT are High efficiency which is higher than 90% is possible, High power transfer of up to several kilowatts, Good galvanic isolation, Suitable for applications from low-power smartphones to high-power EV. The potential disadvantages of IPT are Limited transmission distance with varies from cm to m, the significant eddy current loss is generated in nearby metals which limits its application area. The key advantages of MPT are long effective transmission distance up to several km, suitable for mobile applications, potential to transfer several kilowatts of power. The potential disadvantages are low efficiency less than 10% for high power applications(such as transfer several kW power or more), complex implementation. The key advantages of LPT are long effective transmission distance up to several km, flexible device, suitable for mobile applications, potential to transfer several kw power. The potential disadvantages are low efficiency around 20% or less, the line to sight to the receiver [4, 5].

To date, both the CPT and IPT can offer the capability of supporting high power transfer above kilowatt level with high efficiency in the close distance. However, the transferred power of these technologies attenuates quickly with the increase of the transmission range. Thus the power transfer distance is largely limited. Because of the ease and low cost of implementation, these near field WPT technologies have found niche applications in everyday life, such as wireless charging of consumer electronics, electric vehicles (EV), robot manipulation, and biomedical implanted devices [4, 5].

1.2.Problem statement

When the electrical signal is modulated with the optical wave, the electrical signal is distorted due to the large difference between the frequency value of the electrical signal equal to 60Hz and the frequency of the light wave which equals 400 -500THz for the wavelengths used, Therefore, this will affect the received optical signal in the (LDR) optical sensor. Also, when the optical signal spreads in the optical fibers, it is exposed to a deterioration in the intensity of the optical signal, which also reduces the received signal in the optical sensor.

1.3. Aim of the project

1. Study and design of a system for transmitting alternating electric current using LED.
2. Transfer of alternating electric current in an optical fiber by modulating an electric current on an optical wave.
3. LED power measurement before and after alternating electric current modulation.
4. Measuring the LED power before and after the optical fiber was connected.

CHAPTER TWO

TRANSFER AC CURRENT IN OPTICAL FIBER USING LED

2.1. Introduction

LiFi is one of the newest communication technologies that aim to improve upon current technology by making use of visible light communication as opposed to the radio waves used by WiFi. Its introduction actually serves a dual purpose as it aims to provide overhead illumination to households as well as facilitate the transfer of data [5].

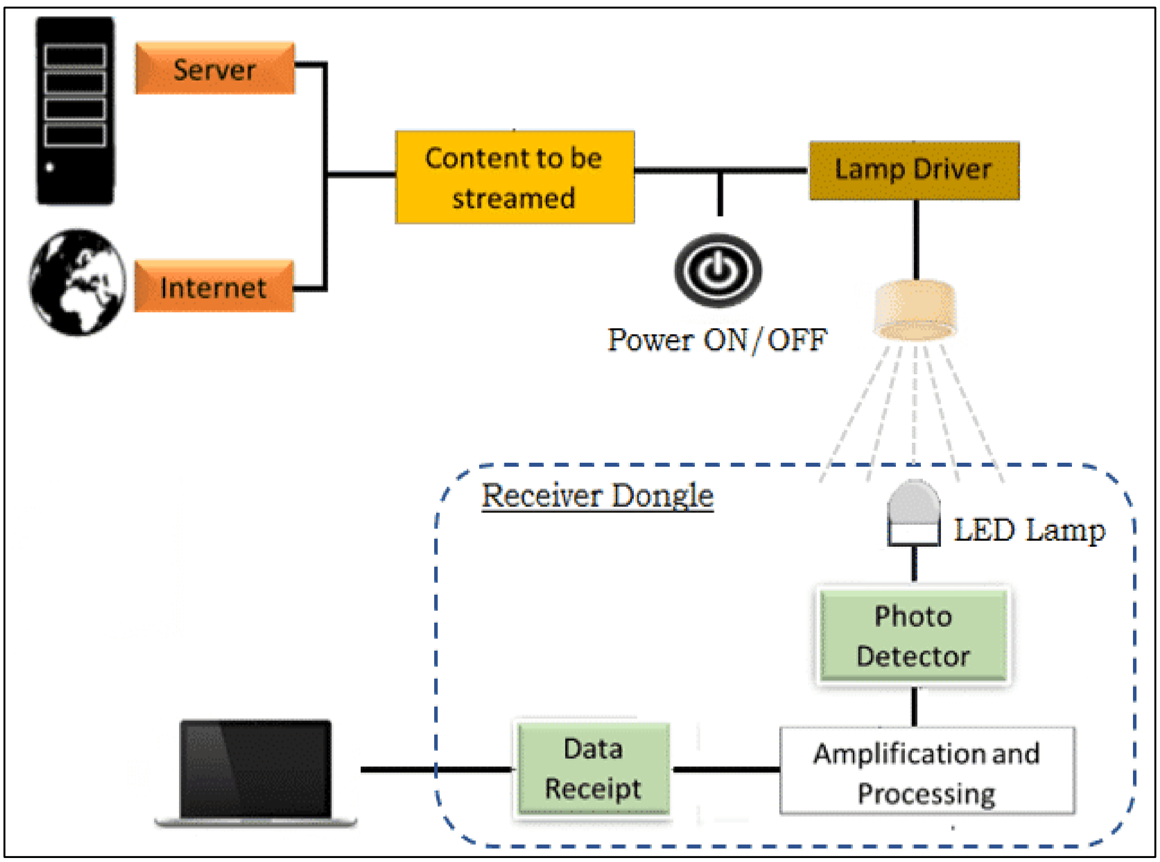


Figure 2. 1: LiFi system

The introduction of LiFi presents a new paradigm for optical wireless technology as it aims to provide connectivity within a localized environment while forgoing the use of fiber optic cables as a transfer medium for light. Instead, it makes use of overhead LED lighting commonly found in households as a medium of transport. Currently, the technology is able to achieve a maximum data transfer rate of 224 gigabits per second – the equivalent of downloading 18 HD movies every second [5].

Whereas WiFi technology effects data transfer on radio waves, LiFi takes the next revolutionary step in wireless evolution and embeds and transfers data in visible light beams, thereby allowing LiFi to take full advantage of the vastly greater light spectrum bandwidth capacity that is provided by the light spectrum. Data is captured in modulated light frequencies of a solid-state LED light source and is then transmitted and received by LiFi-enabled devices. A photosensitive detector demodulates the light frequency signal and converts it back into an electronic data stream and – in so doing – allows for faster-than-ever, more secure, bi-directional wireless communication. Since data is transmitted through light, then that must mean that LiFi does not work in the dark, Not necessarily. If the light is completely turned off, there is no LiFi. But LiFi enabled LED lights can be dimmed low enough that a room will appear dark and still transmit data. There is a consistent performance between 10 and 90 percent illumination. Currently, LiFi can still effectively perform at light levels down to 60 Lux [6].

2.2. Principle of Operation

There are two modulation classes used in the optical communication system.

2.2.1. The direct modulation (DM)

The transmitted signal generated from the direct modulation is shown in the following scheme:

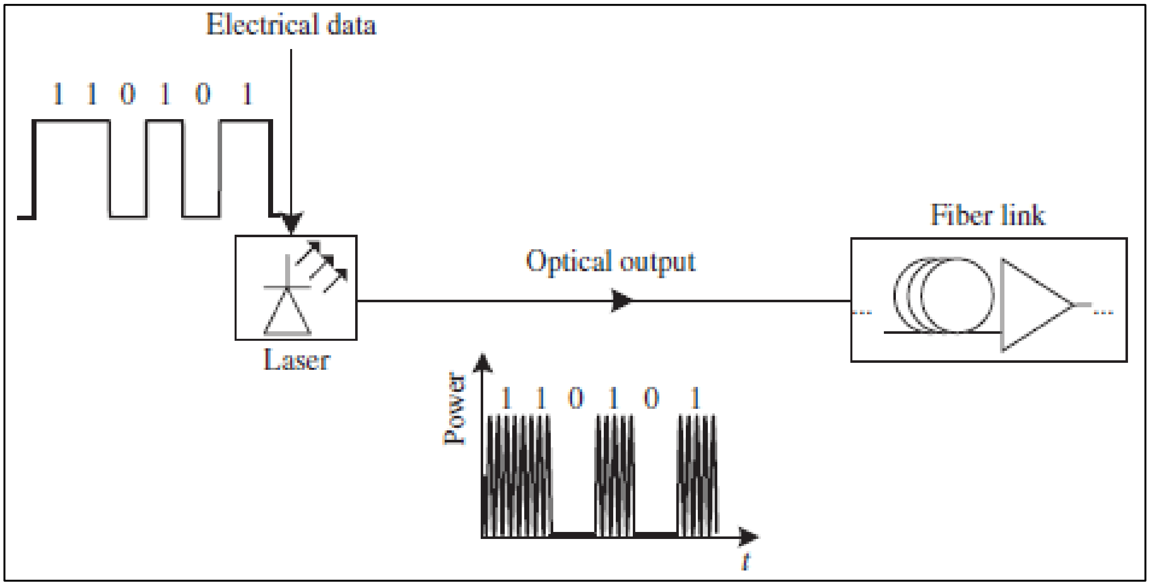


Figure 2. 2: The Direct modulation of semiconductor laser

As shown in the figure 1, the electrical data modulate the drive current of the laser, when the “1” of electrical data is present, the laser is turned on and, therefore, the electrical impulsion is encoded onto the presence of optical. Signal in the fiber link. This modulation present a great amount of chirp that defined as a rapid variation in the instantaneous frequency of the laser caused by the refractive index changes in the active layer due to the carrier density population [6]. Where the chirp and dispersion effect of the fiber will introduce pulse broading. For that, the performance of this modulation class still limited for data rate (< 10 Gb/s) and short distance [7].

2.2.2. The external modulation (EM)

The second modulation type known as external modulation it is applied by using an external component to modulate the optical signal as given in the following figure:

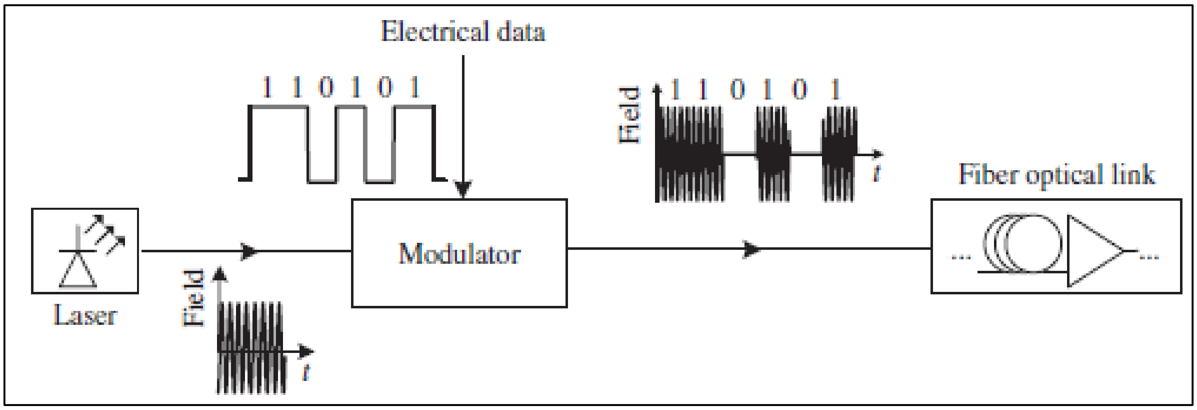


Figure 2. 3: A transmitter using an external modulator

As shown in the figure 2, the laser is turned on at all the time, and we used as external modulator component the MZM modulator having two wave guides, two junctions, and RF/DC traveling wave electrode as shown on the figure 3. Figure 3 shows that the external component consist of two waveguide constructed by titanium which is implemented into the lithium niobate substrate, it has as characteristics electro-optic effect [7].

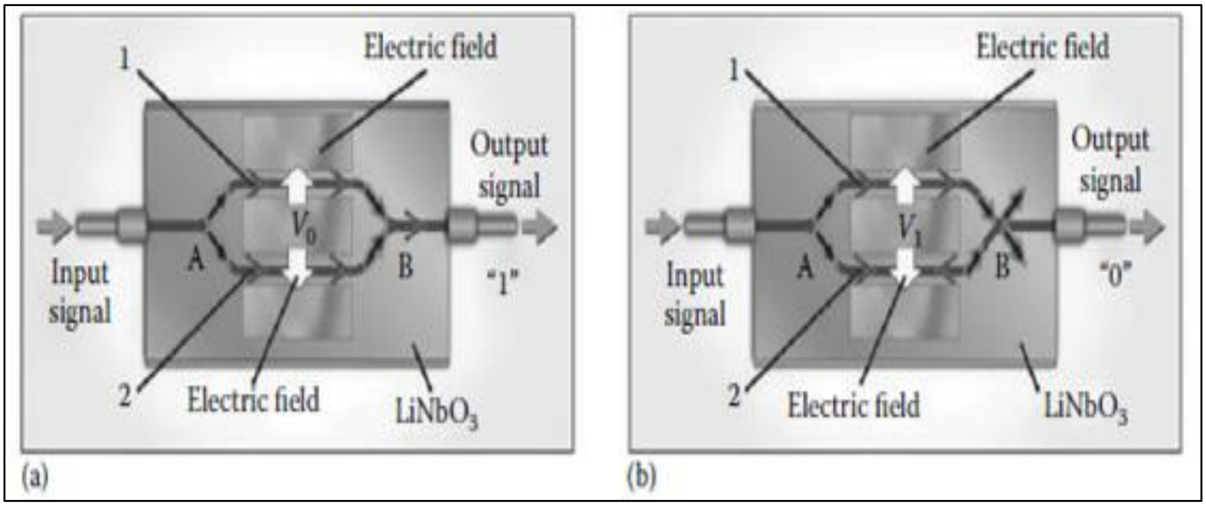


Figure 2. 4: Intensity modulation using interferometricPrinciples (MZM modulator) in guide wave structures in LiNbO3. (a): Constructive interference mode (bit: 0 1), (b) destructive interference mode –(bit:0). Optical guided wave paths 1 and 2. Electric field is established across the optical waveguide.

2.3.Advantages of optical fiber communication

Communication using an optical carrier wave guided along a glass fiber has a number of extremely attractive features, several of which were apparent when the technique was originally conceived. Furthermore, the advances in the technology to date have surpassed even the most optimistic predictions, creating additional advantages. Hence it is useful to consider the merits and special features offered by optical fiber.[8].

1. Enormous potential bandwidth.
2. Small size and weight.
3. Electrical isolation.
4. Immunity to interference and crosstalk.
5. Signal security.
6. Ruggedness and flexibility.
7. System reliability and ease of maintenance
8. Potential low cost.

2.4. Impairments in optical fiber transmission

The optical fiber is often seen as a perfect transmission medium with almost limitless bandwidth, but in practice the propagation through optical fiber is beset with several limitations especially as distance is increased to multi-span amplified systems. As the transmission systems evolved to longer distances and higher bit rates, the linear effect of fibers, which is the attenuation and dispersion, becomes the important limiting factor. As for WDM systems that transmit multiple wavelengths simultaneously at even higher bit rates and distances, the nonlinear effects in the fiber beginning to present a serious limitation [9].

The success of high bit rate long haul point-to-point optical transmission networks depend upon how best the linear and nonlinear effects are managed. the various fiber induced impairments and their negative influence in restricting the achievable capacity of the transmission link can be described. The major linear effects include group velocity dispersion (GVD) of standard single-mode fiber, fiber loss, adjacent channel X-talk, polarization mode dispersion (PMD), accumulated ASE noise, etc. The nonlinear effects on the other hand include self phase modulation (SPM), cross phase modulation (XPM), stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), and four-wave mixing (FWM). The most effective linear impairments can be classified as follows [9]:

❖ Attenuation :

Attenuation causes the decay of signal strength, loss of light power as the signal propagates through the fiber. Attenuation in optical fibers is caused by intrinsic factors which are scattering and absorption and by extrinsic factors which include stress from the manufacturing process, environmental and physical bending [9].

❖ Chromatic Dispersion:

Light pulses representing data have a definite spectral width. Because of chromatic dispersion in an optical fiber different wavelength propagate at different speeds thereby resulting pulse reading. If left unmanaged, pulse spreading eventually results in inter-symbol interference when adjacent pulses overlap, leading to errors in the recovery of transmitted bits [9].

❖ Group velocity dispersion:

Group velocity dispersion (GVD) is the main cause for pulse spreading and thereby introduces the inter-symbol interference in a received signal [9].

❖ Polarization mode dispersion:

Once dispersion is managed, polarization mode dispersion becomes the most dominant linear effect to limit the channel capacity [9].

❖ Adjacent channel crosstalk:

Adjacent channel X-talk is very common with all forms of communication system. In dense WDM optical communication system the adjacent channel X-talk is very significant and limits the minimum separation of two adjacent channels with an acceptable penalty. For narrow channel spacing, there is a partial overlap of channels in frequency domain. The effect depends upon large number of parameters such as channel spacing and filtering characteristics of multiplexers and demultiplexers [9]

CHAPTER THREE

Circuit Design

3.1.Introduction

In order to find a new way to transmit the electric current, the li-fi system is used, and instead of entering the data into the system, an alternating electric current is entered so that the electric current is included with the optical wave using the LED. Figure 3.1 shows the PCB design of a system. In this chapter, two experimental setups are described, including the link of the transmitter, the transmission link (in free space and in the optical fiber) and the receiver.

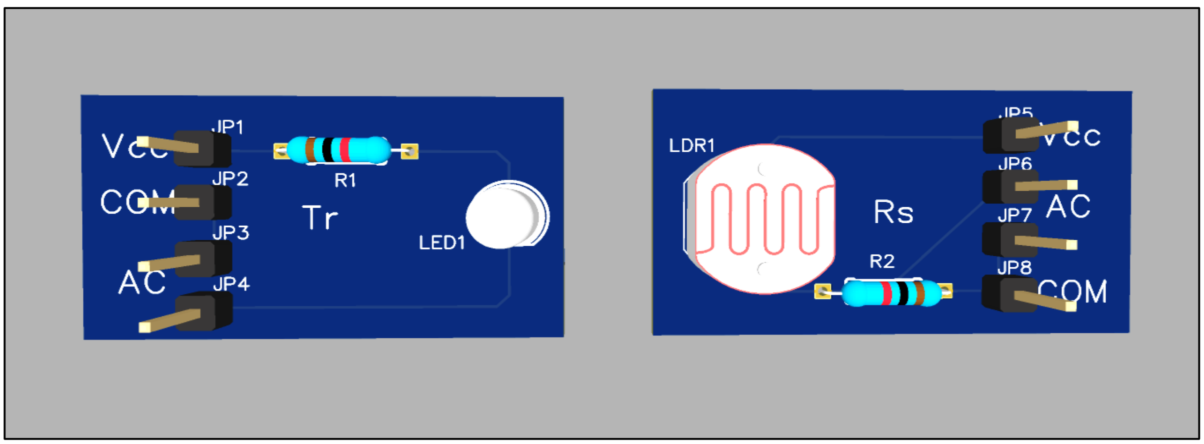


Figure 3. 1: The PCB design of a system

3.2.Phase Generator

3.2.1. Three-Phase Generator

In the beginning, Figure 3.2 shows the design of the 3-phase generation system, which consists of a DC-motor and a brashless-DC motor, and a connector is placed between their shafts, in order for the DC-motor to rotate the brashless-DC motor. at the output of brushless-DC motor the 3 equal resistors were connected in Y-configuration and resulted in a Sine signal of 10 volt pik-pik and frequency of 500Hz.

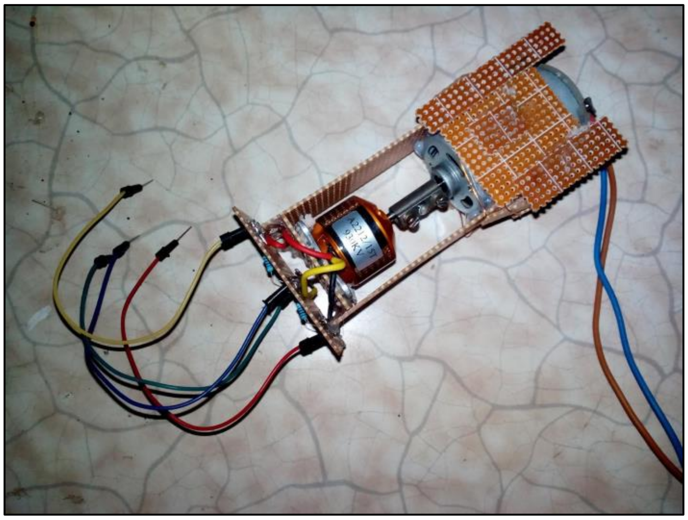


Figure 3. 2: The design of the 3-phase generation system

3.2.2. Single-Phase Generator

Figure 3.3 shows the 220 to 6 volt transformer which used to resulted in a Sine signal of 12 volt pik-pik and frequency of 60Hz.

Figure 3. 3: The Single-Phase Generator

3.3. Transmitter

At first, Figure 3.4 shows the design of a Transmitter system, the transmitter section comprises 3 channels separated. Each channel consists of a light-emitting diode (LED) that modulates an alternating current (AC) signal on the photovoltaic guide to become a pulse LED. Next, the 220 ohm resistor was connected to the positive pin of the three LED's and the positive pin of the vcc was connected to the resistor and then the AC source pins were connected in series between the negative pin of the vcc and the negative pin of the LED.

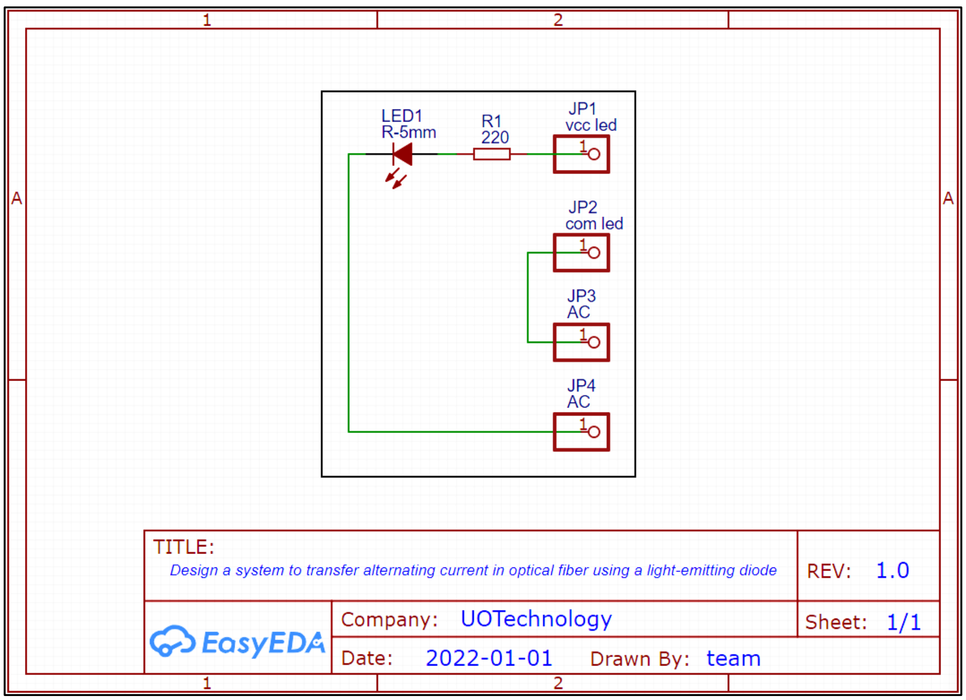


Figure 3. 4: The design of a Transmitter system for single channel

3.4. Receiver Section

In receiver section, Figure 3.5 shows the design of a receiver section, Photoresistor LDR is used for optical to electrical conversion (demodulation).The positive end of the Vcc is connected to one of the ends of the photoresistor, and the other end of the photoresistor is connected to one of the ends of the electrical transformer. Then an electrical resistance of 5.6K ohm is connected with the terminal of the photoresistor, which is connected with the electrical transformer, and the other end of the electrical resistance is connected with the other end of the electrical transformer and with the negative terminal of Vcc.

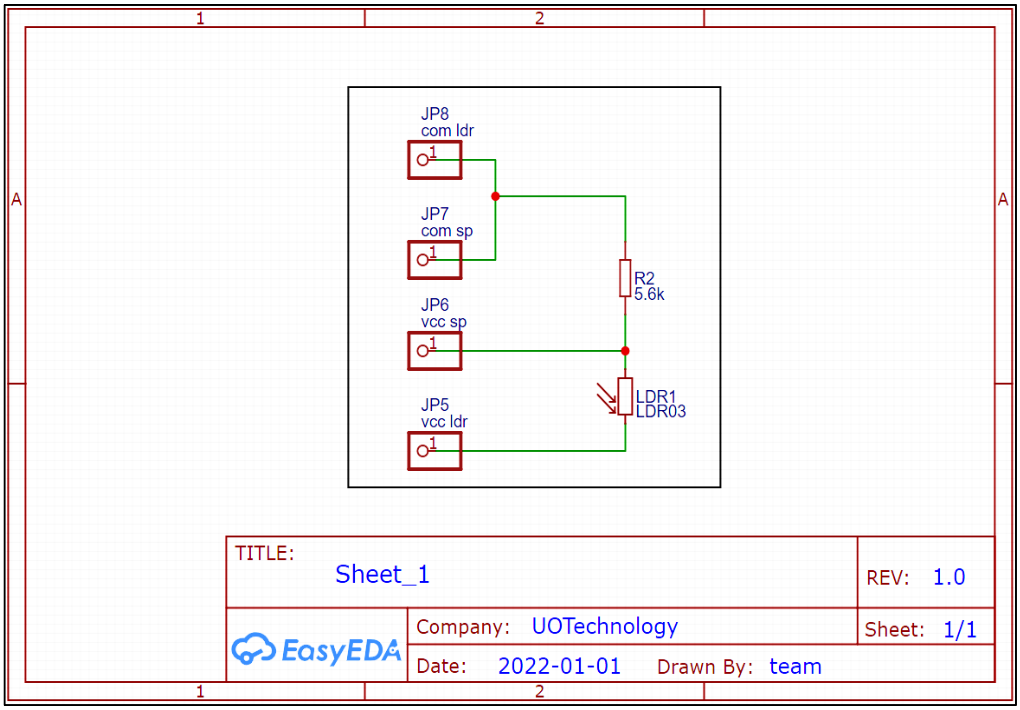


Figure 3. 5: The design of a receiver section for single channel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1.Introduction

In this chapter, the performance of the device (transmitter system and receiver system) in the system of transmitting alternating current in the optical fiber using LED is explained by operating the system in a realistic way. Different parameters such as, the photon energy of each LED (before and after alternating current), the AC voltage entering the transmitter, the current entering the transmitter, the AC voltage leaving the receiver, and the output current from the receiver are studied.

4.2.Results and Discussion

4.2.1. Power measurement in free space

Figure (4.1) shows the power of a photon for each wavelength before the alternating current is included and after the alternating current is included in the transmitter circuit in the alternating current transmission system in the optical fiber using the LED.

The values are measured using a digital photon power meter shown in Figure (4.2). The results are obtained by operating the transmitter circuits shown in Figure (4.2b) and each circuit is fed with a voltage of 9 volts, and the power is measured for each 5 mm LED, then the current is entered The alternator is connected to the transmitter circuit by connecting the 6-220 volt transformer with each circuit as shown in Figure (4.2c) and the power is calculated for each LED and the signal is tracked using an oscilloscope for all chanel and for (input and output signal) as showen in figures (4.2a) to (4.2f).

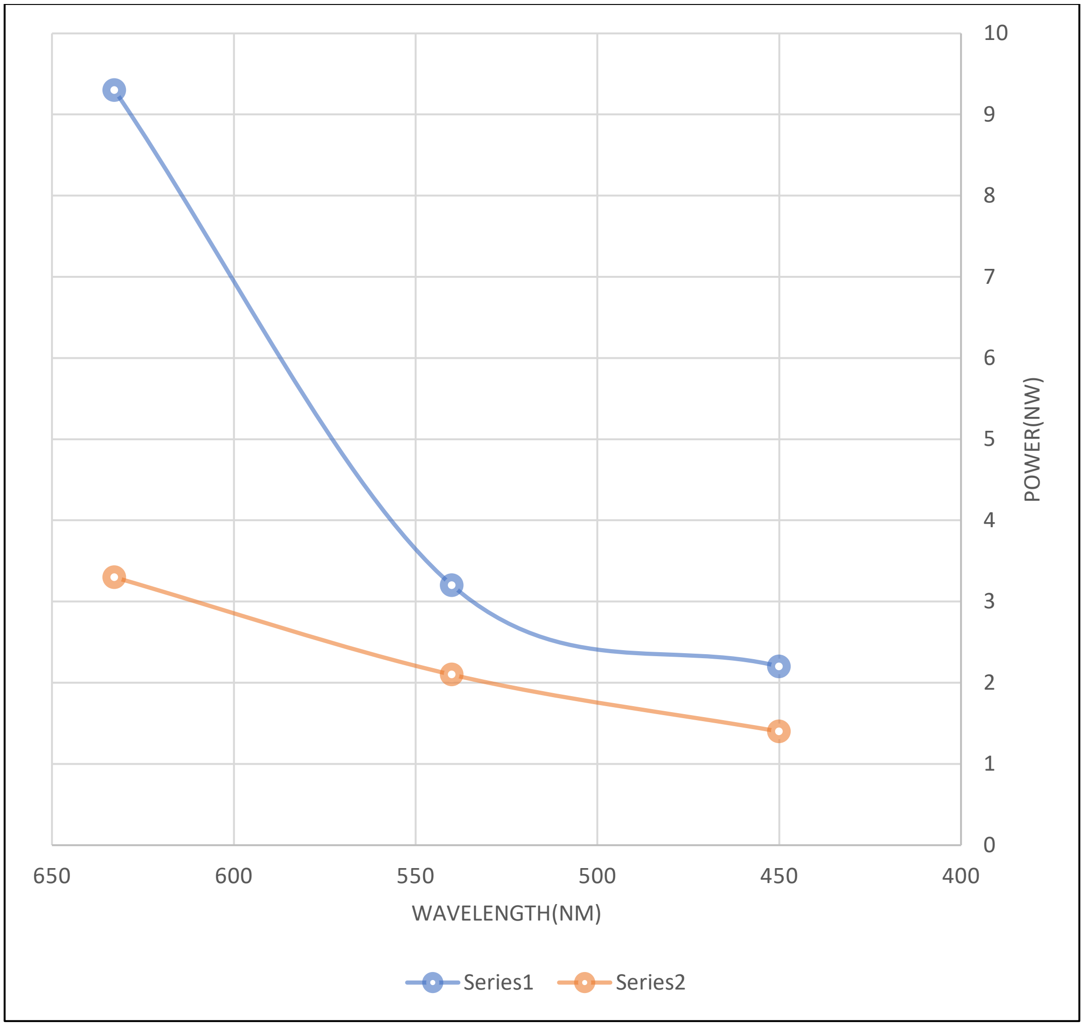


Figure 4. 1: Photon power of LED before AC modulator and after AC modulator

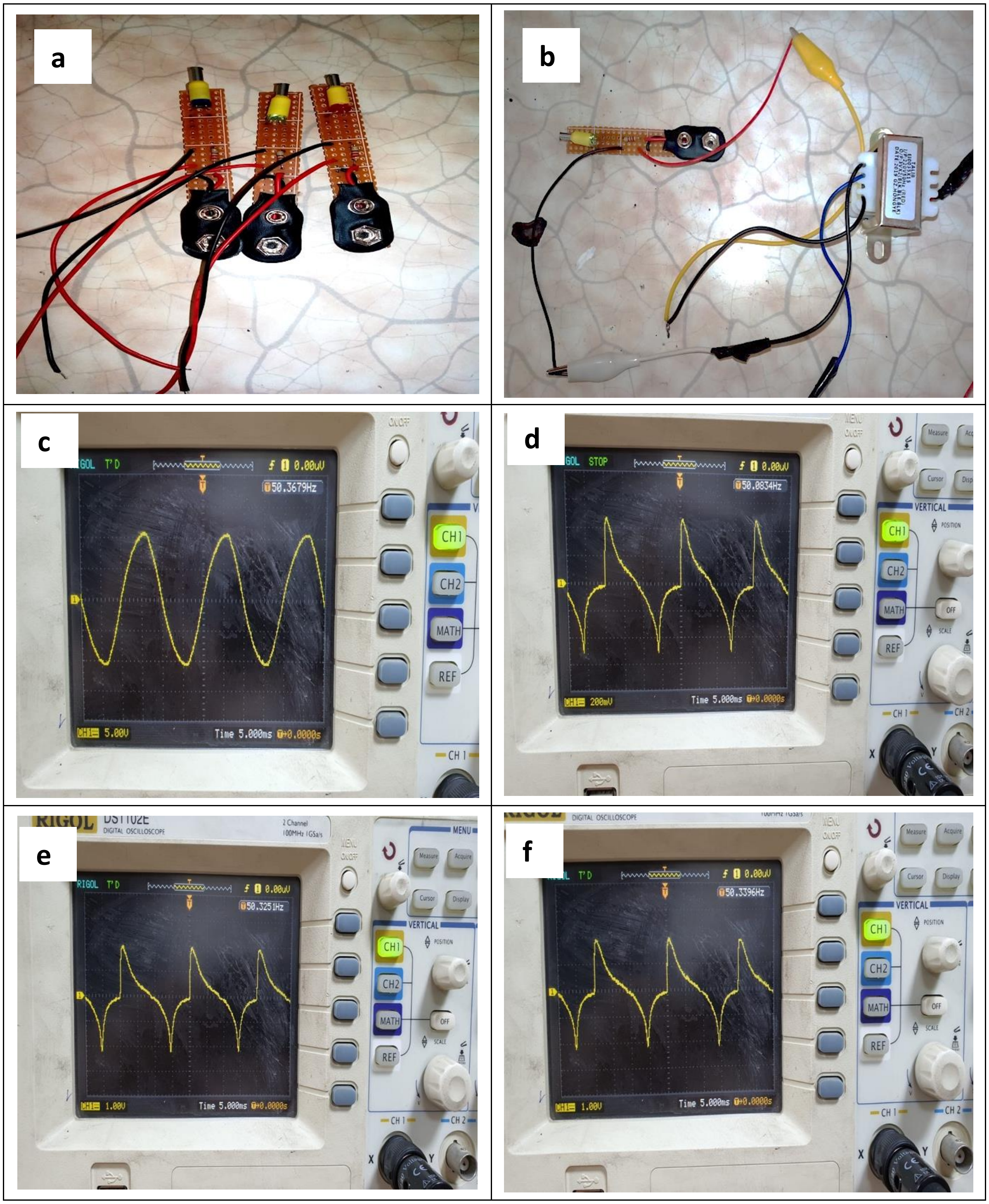
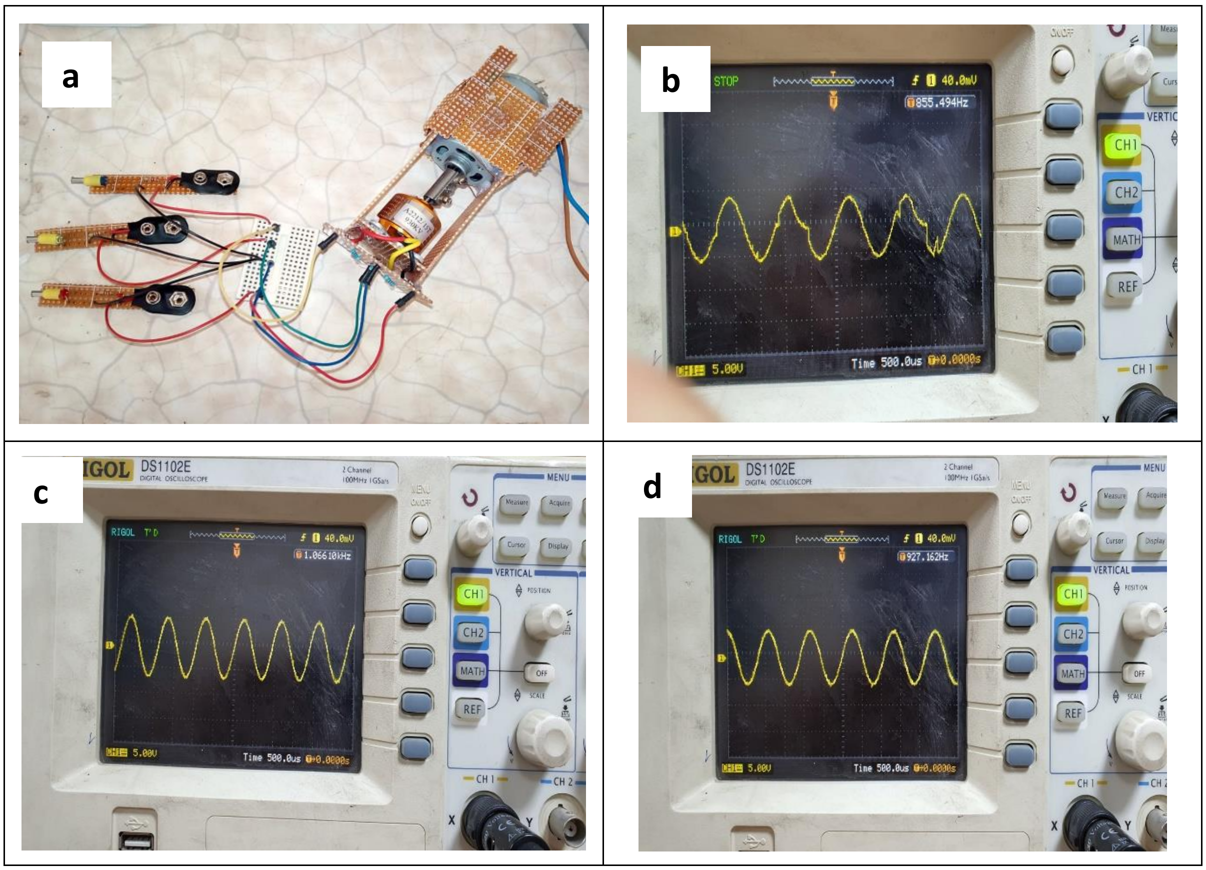


Figure 4. 2: Single phase transmission(a) LED circuits, (b) Single phase transmitter, (c) Input signal, (d) Output signal of blue LED, (e) Output signal of green LED, (f) Output signal of red LED

The alternator is then connected to the transmitter circuit by connecting the Three-Phase Generator with each circuit as shown in Figure (4.3a) and the signal is tracked using an oscilloscope for all chanel and for (input and output signal) as showen in figures (4.3b) to (4.3g). One of the problems that occurred was that the power meter had some noise and there were external effects such as heat and light scattered around the device, and also when the power values of each LED were taken when alternating current was included, two values were obtained for each LED because the LED was working As a puls source, the mean value of each LED was taken.



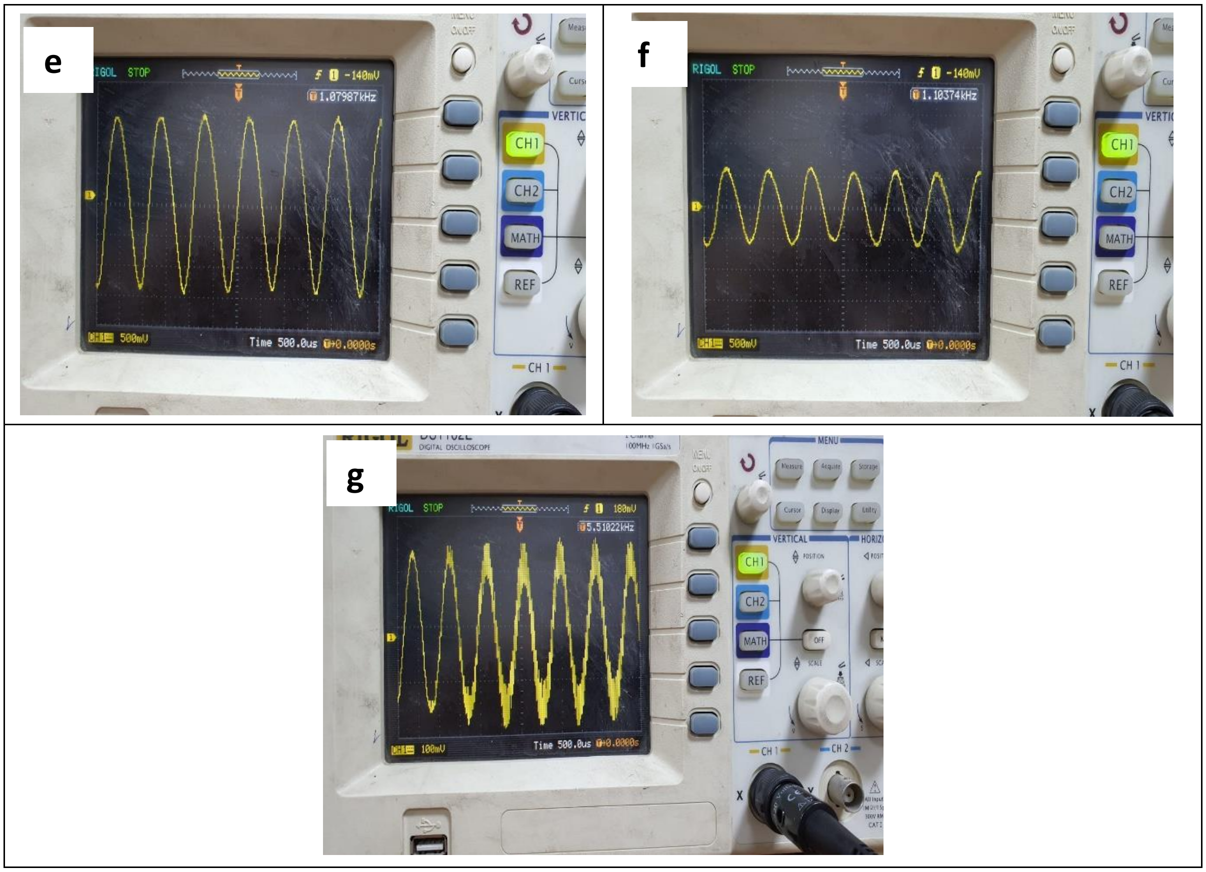


Figure 4. 3: Three-phase input – output signal (a) Three phase circuit, (b) Input signal of red LED, (c) Input signal of green LED, (d) Input signal of blue LED, (e) Output signal of blue LED, (f) Output signal of green LED, (g) Output signal of red LED.

4.2.2. Power measurement inside plastic optical fiber

Figure (4.4) shows the power of a photon for each wavelength during the single phase is modulated and during the three-phase generator is modulated in the transmitter circuit in the alternating current transmission system in the optical fiber using the LED.

The values are measured using a digital photon power meter. The results are obtained by operating the transmitter circuits and the plastic optical fiber was connected with LED in transmitter circuits shown in Figure (4.5) and each circuit is fed with a voltage of 9 volts, then the current is entered the alternator is connected to the transmitter circuit by connecting the 6-220 volt transformer with each circuit and the power is calculated for each LED and the signal is tracked using an oscilloscope for all chanel and for output signal as showen in figure (4.5b) and (4.5c), (While no signal was obtained from the red LED). The current is applied to the alternator is connected to the transmitter circuit by connecting the Three-Phase Generator with each circuit and the plastic optical fiber was connected with LED in transmitter circuits and the signal is tracked using an oscilloscope for all chanel and for output signal as showen in figures (4.5d) to (4.5f).

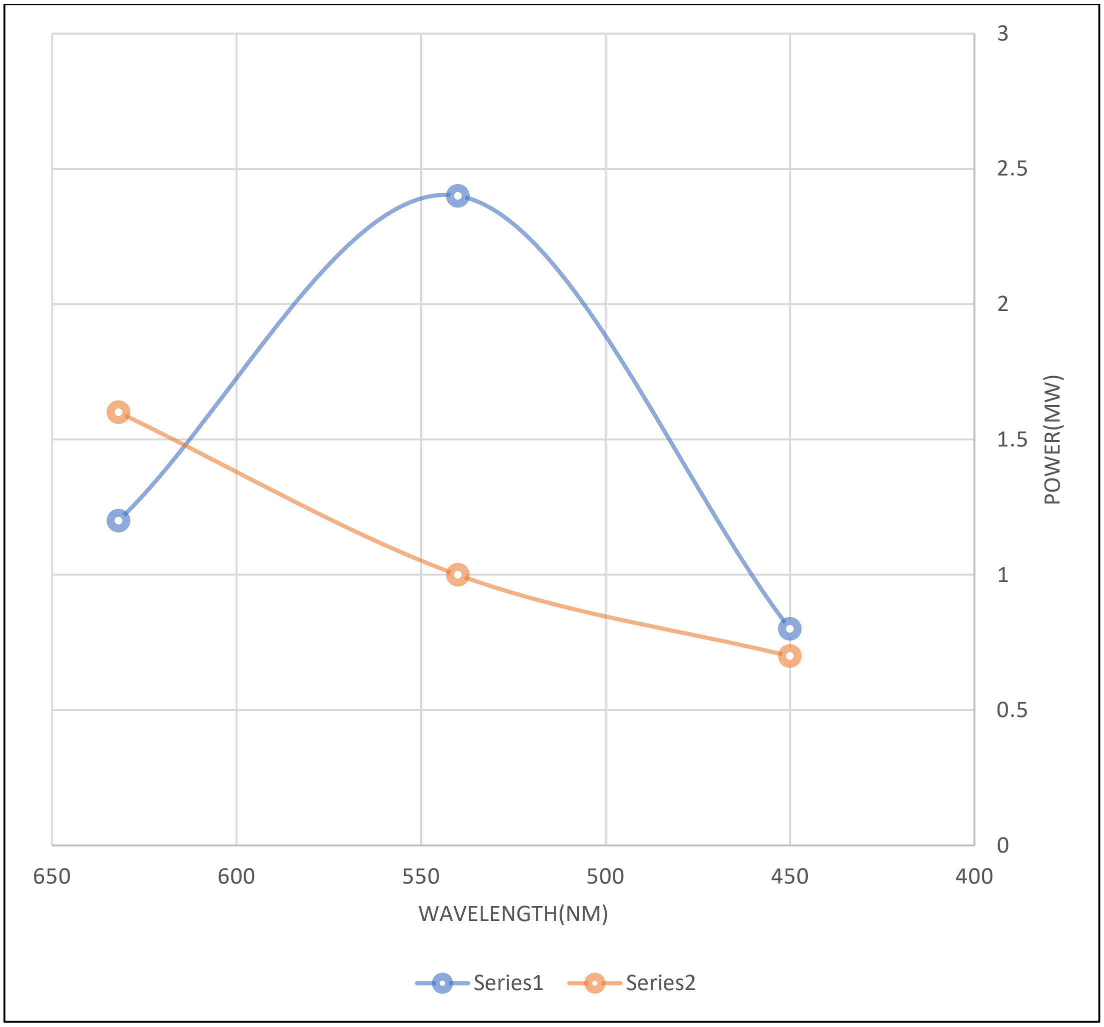


Figure 4. 4: Photon power of LED with single phase and three-phase

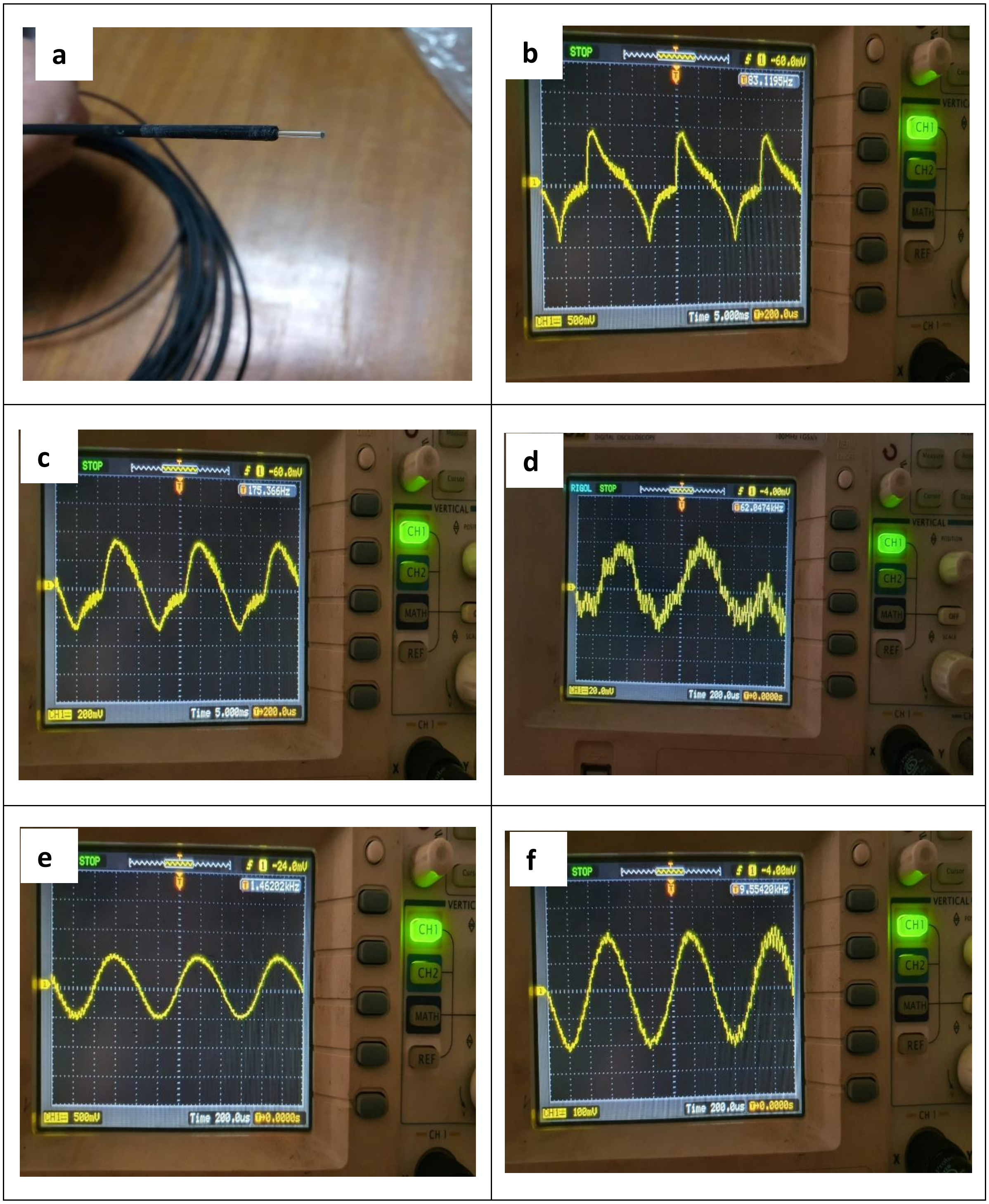


Figure 4. 5: Output signal,(a) 10 m plastic optical fiber, (b) Output of green LED, (c) Output of blue LED, (d) Output of red LED, (e) Output of single phase of green LED, (f) Output of single phase of blue LED.

CHAPTER FIVE

CONCLUSIONS

In this project, a design of single and three – phase alternating current based optical signal transmission was proposed. The output signal of different channels (free space and plastic optical fiber) were established and analyzed. It was concluded that signal tramission of blue wavelength has a lower power level compared to green and red light emitting diodes. The diffeculties of this project is to maintain perfect alignment between the LEDs and the plastic optical fiber. Further, more signal loss is found due to waste of signal power due to coupling loss. However, a number of advantages were concluded which they are: low cost design, simple circuit implementation, and suitable controlling of the circuit.

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