Faculty of Electrical Engineering

Real Time Monitoring and Water Leakage Detection System in Underground Pipeline

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B011310162

Bachelor Of Electrical Engineering

(Control, Instrumentation and Automation)

2017

Real Time Monitoring and Water Leakage Detection System In Underground Pipeline

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A thesis submitted
in fulfillment of the requirements for the Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this report entitled “Real Time Monitoring System and Water Leakage Detection in Underground Plastic Pipeline” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Signature : …………………………………………………………

Supervisor Name : Dr Rozaimi Bin Ghazali

Date : …………………………………………………………

DEDICATION

To my beloved family especially my mother

ACKNOWLEDGEMENT

Firstly, I would like to thank God for His love and blessing that I had complete my Final Year Project.

Then my gratitude goes to my supervisor Dr. Rozaimi bin Ghazali for his guidance, support and valuable advices from the start until completion of this project. It would be very hard to complete this Final Year Project without his valuable support and encouragement.

With this opportunity, I would also like to thank my family for allowing me to pursue my undergrad studies in Bachelor Degree of Electrical Engineering (Control, Instrumentation & Automation) honors and for giving me the moral support and motivation. Thanks for their unconditional love they had given to me.

Finally, I would to thanks my classmates, others who involve directly and indirectly for their kind support and opinion that are very useful in my project implementation.

ABSTRACT

Water leakage is posing a major threat for water supplier industry especially in developing country such as Malaysia. If there is no immediate action to counter the problem, it could lead more downside to the water supplier industry. This project implements a monitoring system and water leakage detection for a distribution buried plastic pipeline by using a monitoring system to detects the location of the leak source inside the pipeline. The monitoring system display a real-time pressure data of a pressurized pipe by using a GUI (graphical user interface) via LabVIEW software. The uses of several pressure sensors install along the pipeline are the keys for the complete processes. To simulate real leak situation, a broken pipeline was design. Threshold pressure value to trigger leakage alarm is set in the LabVIEW to avoid any false alarm indication in non-leak situation. To enhance the capability of this system, the leak detection system is developed based on cross correlation method to detect the estimation of leak location. Apart from that, for effectiveness of the pressure sensors, malfunction alarm is set when pressure sensor is not working in the monitoring system. LabVIEW software and NI myRIO-1900 is used as the main processing and control unit for this project development.

ABSTRAK

Kebocoran air menimbulkan ancaman utama bagi industri pembekal air terutama dalam membangunkan negara seperti Malaysia. Jika tidak ada tindakan segera untuk menangani masalah ini, ia boleh membawa lebih banyak keburukan kepada industri pembekal air. Projek ini menggunakan satu sistem pemantauan dan pengesanan kebocoran air bagi saluran paip plastik yang dikebumikan dengan menggunakan sistem pemantauan untuk mengesan lokasi sumber kebocoran dalam paip. Dalam projek ini, sistem pemantauan akan memaparkan data tekanan masa sebenar paip bertekanan dengan menggunakan GUI melalui perisian LabVIEW. Untuk mensimulasikan keadaan kebocoran sebenar, saluran paip pecah telah direka bentuk dan dipasang di jarak yang tertentu di dalam paip. Semasa kebocoran, keadaan GUI dalam LabVIEW akan memaklumkan kakitangan bekerja dari lokasi sumber kebocoran melalui sambungan diantara NI myRIO-1900 dan pengesan tekanan. Untuk meningkatkan keupayaan sistem ini, sistem pengesanan kebocoran dibangunkan berdasarkan kaedah silang korelasi untuk mengesan lokasi kebocoran. Sementara itu, bagi meningkatkan keberkesanan pengesan tekanan, penggera kerosakan akan dicetuskan apabila sensor tekanan tidak berfungsi atau memaparkan bacaan sifar tekanan dalam sistem pemantauan. perisian LabVIEW dan NI myRIO-1900 digunakan sebagai pemprosesan dan kawalan unit utama untuk pembangunan projek ini.

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CHAPTER 1

INTRODUCTION

This chapter briefly describes the background of study for this project. The motivation and problem consider relating to this project is also explained thoroughly in this chapter. Lastly, objectives and scope of project are listed accordingly.

1.1 Background of Study

Water represents one of the necessity things in this world and it plays vital roles in our daily life [1]. Without water, there is no way human being or any sort of living things can live in this beautiful earth. Thanks to the water supplier industry, end user or consumer can enjoy a clean raw water intake every day provided by the industry, but it comes with a price of course.

In Malaysia, the current population to date is 31.7 million people with a 1.5% annual growth rate [2]. To enable all the consumer get consumable raw water intake, a water distribution network pipeline was designed and constructed by the water supplier industry. The pipeline network is usually buried underground [3]. Imagine all the metal and plastic pipelines buried beneath us. With the increase in number of population, big responsibility holds at the shoulder of water supplier industry. It is crucial and essential to make sure the water supplier

industry objective to supply consumable water continuously to consumer can be fully achieved without any water disruptions [4].

One of the hardest challenges need to be tackle by the water supplier industry is to minimize treated water loss due to leakage occurred along the pipeline [4], [5], [6]. Even though technology rises proportionally with time, flaws and imperfections found in current leak detection technology are unavoidable such as the commonly used technique which is acoustic technique for detecting leaks in a plastic pipeline [1], [6], [10]. A recent study was made and the result was, in most of water distribution network, a significant percentage ranging from 20 % to 30 % of water production from the treatment plant tend to leak along the pipeline before reaching up to consumer [10]. Leakage is not an issue to joke around but it is a serious threat for the water supplier industry. The water supplier industry had to suffer loss from leakages due to high cost in purifying the water to consumer also known as NRW (non-revenue water) [6]. NRW is defined as the differences between total supply of purified water from the treatment plant and the total meter quantity to the consumers [3], [7]. Malaysia has a very high rate of NRW at 35.6% currently [7]. The NRW rate is more than one third of the country total treated water volume with an estimation average loss of RM2.6 billion in profit annually [7]. This large amount of money will lead to undesirable impact to the country economic growth indirectly [5], [8], [10].

The root cause of leakage usually associated with an aging pipeline, a very volatile water distribution infrastructure, corrosion and the composition of soil [1], [8]. Due to location of the pipeline buried beneath and limited visibility access, regular inspection to detect leaks are almost impossible to execute perfectly even with the help of current high end technology [1]. Hence, a wireless monitoring system is a must in any pipelines system. This technology would easily overcome the less visibility problem.

By having a wireless monitoring system, surely it will benefit the water supplier industry in lots of aspect compared by using traditional wired monitoring system [8]. In term of cost, water supplier industry can save lots of expenses as they could minimize the installation cost due less wired is required. Since sensor is be buried underground and less wired, for sure vandalism or stolen cables activities can be eliminated as well.

After a certain period and large amount of money invest, a sudden increase in public awareness and their love towards the environment had called for drastic changes [10], [4]. Low cost and reliable technology of a leakage detection system are in demand now [9], [10].

In this project, real time monitoring system is used to monitor the pressure inside the pipeline by transferring the pressure data inside the pipeline to the monitoring system and any sudden drop in pressure will trigger leakage alarm. Wireless real time monitoring system is the most favorable technique to be used to monitor the pressure activity inside the pipeline compared to hardwired monitoring system due to simplicity of the overall system and less hard wire is required.

1.2 Motivation

High staggering rate of NRW at 35.6% in Malaysia had given the motivation to develop a system that could help to reduce the country NRW rate. A real time wireless monitoring and water leakage detection system inside an underground plastic pipeline is a sophisticated system to study and it will enhance a lot of knowledge in term of engineering aspects. This project uses several advance techniques such as wireless transmitting, development of a GUI in the monitoring system and statistical approach via cross correlation method in detecting leakage as well. Thus, in term of engineering perspective especially in instrument and control engineering discipline, it will benefit a lot.

1.3 Problem Statement

Distribution pipeline from the storage tank to the consumer or housing area usually can be found buried underground with a minimum depth of 30 cm. The length of the distribution pipeline itself could extend up to more than hundreds of kilometers. When leakage occurs, tracing the exact location of leakage would be a major problem. To examine the whole distribution pipeline is very time consumable and required lots of human effort which will cost lots amount of money. In detecting leakage, human intervention is not a suitable method even with the help of high end technology detector hold in the human hand.

A real-time monitoring system which can detect leakage through the monitoring system itself is needed to solve this problem. Especially when the capability of this system is enhanced by using a wireless network to continuously transmit the real-time pressure data to the monitoring system. Thus, leads to less hardwired connection which can counter the length of pipeline problem.

1.4 Objectives

The main objective of this project is to develop a wireless leakage monitoring and leakage detection system in an underground plastic pipeline. The objectives of this project can be listed as follows:

i. To develop real time wireless monitoring interactive graphical user interface for underground pipeline system
ii. To design leakage detection system based on pressure characteristics using statistical approach
iii. To evaluate and validate the performance and capability of the system throughout experimental works

1.5 Scopes

To accomplish the objective of this project and enhanced the effectiveness of this system. Few scopes had been considered. The scopes are as listed below:

i. A wireless data transfer network between sensor and the monitoring system using Wi-Fi technology and static IP address will be utilized which capable to communicate with maximum 150 m around the center point.

ii. The monitoring system only capable to measure pressure with the sensor range 0 to 5 bar

iii. Statistical cross correlation technique approach will be used to trace leaks in water pipes

CHAPTER 2

LITERATURE REVIEW

In this chapter, past research and method used related to this project was reviewed. Brief introduction on water leakage problem is described as well at the start of this chapter. Readers would also found the comparison between software based methods to hardware based method for detecting leaks source in plastic pipeline and cross correlation technique in this chapter.

2.1 Introduction

Leakage is a common threat face globally. Due to the impact on economic growth and public health, every country is always on a high alert to solve this problem [6], [8], [10]. Leakage is an unavoidable problem in a distribution pipeline. Through time, aging infrastructure of the pipeline will damage and leads to leakage [1]. Early detection of leakage is crucial to avoid any water disruption which leads to unhappy consumer. With large amount of money invest to counter this threat, it had raised public concern and the public demand to resolve this problem [4], [10].

By referring to [9], there are seven characteristics that had been set in developing a good leak detection system. The seven characteristics are as follows, first is leak sensitivity, location estimation performance, operational change, availability of the system or device, false alarm rate, maintenance requirement, and operation cost. Till today, none of existing leak detection system had the capability to fully meet all the seven desire characteristics [9]. There are several methods that had been used before to detect leakage for an underground pipeline [11], [12], [13], [14]. Generally, this method can be divided into two major categories, hardware based method and software based method.

2.2 Hardware Based Method

2.2.1 Introduction to Hardware Based Method

Hardware based method easily defined as the combination of several components to make up a hardware device [9]. This device is often used to find and pin point the location of the leak source with the help of an embedded sensors inside the device and development of algorithm in programming [9]. There are several types of device that currently been used to detect leakage in a plastic pipeline for this past following year such as visual devices and acoustic devices [9].

2.2.2 Visual Device

Visual device use ground penetrating radar (GPR) technique to detect leaks inside a pipeline. This device detects the changes in surrounding temperature of the pipeline with the help of the temperature sensor [1], [16]. When leakage occurs, the surrounding temperature of the soil at the leak location of pipeline will changes. A GPR requires a radar transmitter and receiver to locate leak source without digging the underground pipeline. To detect leak source, infrared thermography is used to see the soil parameters [9].

Figure 2.1: Assemble of GPR in test area [6]

In [6], a GPR test was conducted to detect leaks by using radar as shown in Figure 2.1. Apart from detecting leaks, the purpose of the test is to find suitable frequency to be used by the antenna to penetrate the buried pipeline. The radar is designed using 100 MHz antennas. The test used 15 cm in diameter of polyvinyl chloride (PVC) pipe and buried in soft clay soil at a depth of 2.4 m.

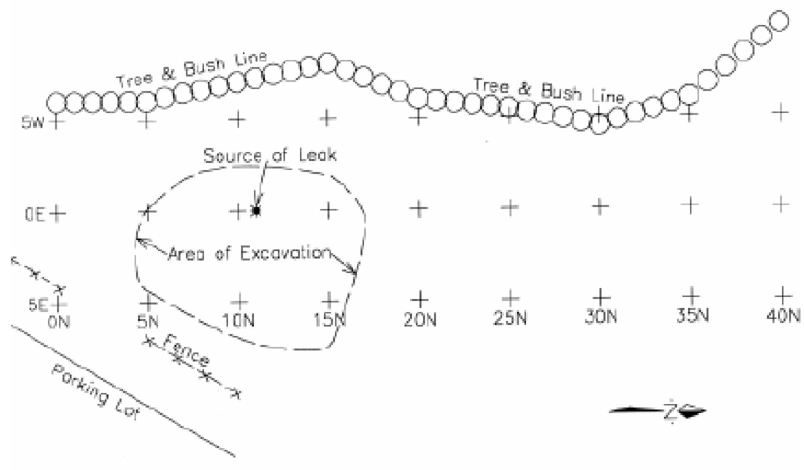

Figure 2.2: Assessment Grid [6]

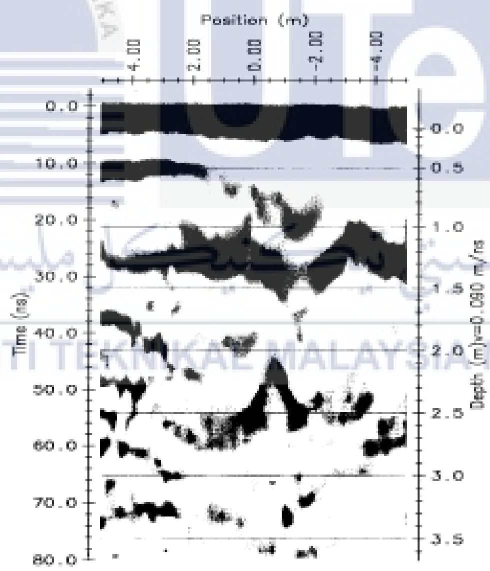

Figure 2.3: Radar Image at points 10N [6]

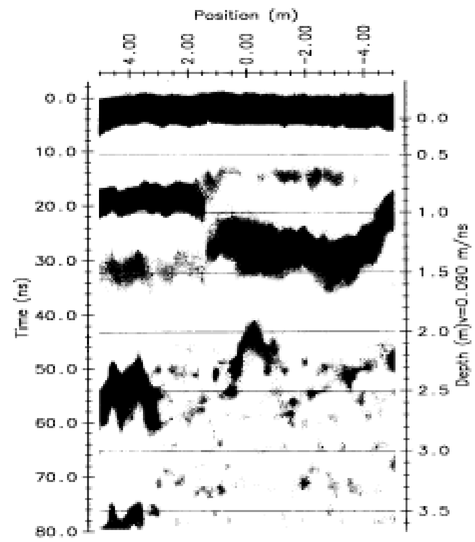

Figure 2.4: Radar Image at points 20N [6]

Figure 2.2 is the overall GPR survey grid for the experimental test. Radar image was obtained at several point 10N, 20N, 0E, 5E, and 5W. Figure 2.3 and Figure 2.4 shows the radar image obtains from the simulation test by the 100MHz antennas at two different points 10N and 20N respectively. From Figure 2.3 and Figure 2.4, the propagation of wave is slower when it is near the leak source.

Based on the result of GPR test above, conclusion can be made [6]. Visual device or GPR methods are a very complicated way to detects leaks source. Suitable frequency for the antennas of the radar needs to be obtained first. Different depth of buried pipeline required different frequency for antennas. From the Figure 2.4 of radar image, 10 m distance from the leak source only shows slight differences of wave propagation compared to radar image of point above the leak source. This identical radar image leads to less accuracy in detecting precise leak source in a buried pipeline. Apart from the effectiveness of this technique, this technique also required intensive human intervention and the data gathered is not in real time.

2.2.3 Acoustic Device

Acoustic leak detection device is one of the common and traditional ways in detecting leaks in an underground plastic pipeline. The idea in developing an acoustic leak detection device is originally to help solving leakage problem in metal pipe [10].

Acoustic leak detection device has the capability to detect the noise or tremor produced by water leaking from pressurized pipeline. The sound induced by the leaks convey through the pipeline to the detecting device which is the receiving unit for leak sound signal. The signal will be obtained by a hydrophone or accelerometer [1], [15].

From the signal, the location of the leak can be obtained by using lots of different method such as by using piezoelectric elements to sense leak-induced sound.

Acoustic leak detection device is still considered the superior method compared to all the hardware based method in detecting water leakage source for buried plastic pipeline [10]. This device may dominate in hardware based method technology for detecting leaks, but there are some issues arise as acoustic method does not work well to detect leak source in an underground plastic pipeline.

Based on the research [10], there are eight factors that are affecting the performance of acoustics leak detection devices including pipe dimension, material of pipe, depth of the buried pipe, composition of soil surrounding the pipe, operational pressure, distortion noise, accuracy and frequency range of the device. Each of the factors gives significant effects to the performance of the device to detect leaks source.

Material of pipe plays a key role as it will contribute to the overall performance of the leak detection device. Acoustics leak detection device work well in metal pipeline as metal give high frequency and has the characteristics to transmit sound more efficiently. While plastic pipeline produce a low frequency at 50 Hz and tends to produce a quieter sound. Human ear has less capability to hear low frequency range.

Thus, acoustic leak detection device only works well with material that could produce high frequency such as metal. It is not recommended to use the acoustic device in detecting leaks for a plastic pipeline as the real leaks location may be overlooked due to the low frequency produce from the plastic pipeline but the cross-correlation technique can be implemented in other reliable technique to detect leakage.

2.3 Software Based Method

2.3.1 Introduction Software Based Method

Software based method is a method often used to create a real-time GUI monitoring system for the pipeline. It uses computer software development to analysis the data obtain from several sensors. There are two types of common sensor usually used to measure the internal data inside the pipe such as pressure and flow sensor. For example, pressure data from the pipeline [9]. Certain threshold value of pressure point set in the software will trigger a leakage indication [9]. This method requires less human intervention compared by using a leak detection hardware device. This method has the potential to become a reliable and robust technology as there is no limitation in future by implementing this method [1].

2.3.2 Review of Current Monitoring System

There are lots of research relating to acoustic technique and ways to overcome the limitation of acoustic technique done in the past. The research may seem promising, but the technique is not compatible to implement in a monitoring system [1].

By having a monitoring system implemented in distribution pipeline network to detect leak source, human intervention can now be reduced. By using sensors to obtain data, monitoring system provide water supplier industry with a continuous monitoring activity internal and external of the pipeline. With the help of this monitoring system, any leakage occurs in the pipeline can be detect easily in short amount of time. Thus, corrective action can be done in fast response time by the water supplier industry to reduce any water loss due to leakage [1]. There are several stages in fulfilling this method.

First stage is obtaining data. Data is obtained through the measurement of sensor. There are two types of measurement, external measurement and internal measurement. For external measurement, the temperature, humidity and properties of soil around the pipelines are measured [8]. While for internal measurement, sensors are placed inside the pipelines to measure the pressure or flow rate of water [8].

Finally, second stage is processing of data. When the data is obtained, it is easy for the monitoring system to process the data. Threshold value corresponding to leakage situation is set at the monitoring system to indicate the location of leakage.

Selection of sensor plays a key role in monitoring system for software based method. The commonly used sensor that is usually implemented in measuring internal data of a pipeline in the monitoring system is flow sensor and pressure sensor. Each of the sensors has the advantages and disadvantages.

Table 2.1: Attributes Comparison for Pressure Sensor and Flow Sensor

Sensor	Pressure	Flow
Leak Sensitivity	Good	Poor
Location Estimation	Good	Poor
Cost	Average	Low

Table 2.1 is obtained from [9] and the attributes are common performance of the leak detection system. Since data acquisition is important as the based for selection suitable sensor.

Current monitoring system carries some drawback to the water supplier industry. Implementation of this system is usually done during the construction phase of the pipeline to avoid any water disruptions. To establish a monitoring system, it requires human effort to access the interior of the pipeline to install several sensors such as flow sensor, mass balancing sensor and pressure sensor to obtain the internal measurement of pipe. Due to length of pipeline may exceed hundredths of kilometers, more hardwired connection is required to establish the connection between the sensors and lastly connecting it to the monitoring center via hardwired as well. The installation cost is high due to the length of copper cables use.

Based on past research from [17], it is also crucial to develop a protection system to avoid the sensor from malfunction as it could lead too inaccurate data reading.

2.4 Comparison between Hardware Based Method and Software Based Method

Each of the method carries advantages and disadvantages in detecting leak source for an underground plastic pipeline. For hardware based method, there are two types of device that are commonly used, visual device and acoustic device. Visual device analyzes radar image while acoustic device analyzes sound signal to obtain the leaks location. The common advantages that could be found, hardware based method are light and easy to carry. But due to limitation of technology, the overall performances of the device are influence by several factors. The major factors are frequency range and material of pipeline. Plastic pipeline does not work well with acoustic device due to the low frequency produce but the cross-correlation technique is practical to apply in detecting leakage. Visual device need to obtain the suitable frequency range for radar antenna design as different depth required certain value of frequency. Table 2.2 shows the comparison between the seven characteristics needed in developing a good leak detection device between visual and acoustic device.

Table 2.2: Performance Comparison between Visual Device and Acoustic Device

Method	Visual Device	Acoustic Device
Leak Sensitivity	Good	Good
Location Estimation	Good	Good
Operational Changes	Yes	No
Availability	No	Yes
False Alarm	Average	High
Maintenance Equipment	Average	Average
Cost	High	Average

Based on the Table 2.2, both visual and acoustic device does meet all the seven characteristics needed in developing a good leakage detection system. The above attributes are based on [9].

Software based method is the monitoring system and this method bring more promising result in detecting leaks compared to hardware based method. Monitoring system provides continuous data measurement such as temperature, flow rate and pressure data of the pipeline. This system could monitor almost the entire of the pipeline distribution network and could be implemented in a large scale. Less human intervention is needed when implementing this system with the right leak detection method and possibility to perform proactive maintenance leads to substantial financial savings.

2.5 Cross Correlation Technique

The cross-correlation technique is one of the favorable and commonly used technique by the water supplier industry in detecting leakage [19], [20]. It is chosen as it is a non-destructive testing method (NDT) and usually applied in detecting location of leakage inside a buried pipeline in industrial or housing area [18]. In industry application, this method is usually the last method to determine the approximate the location of leakage apart from the usage of acoustic emission analysis.

2.5.1 Principle of Cross Correlation Technique

Cross-correlation technique allows to estimate the time delay between two or more measured signals when leaks is simulated. The signal is obtained from a sensor installed along the pipeline. Usually a pressure, flow, or piezoelectric sensor are often used to measure the generates signal. From the estimation of time delay between two signal, the location of leakage inside a pipeline can be approximately determined by performing analyze the correlation coefficient between two signal [20], [21].

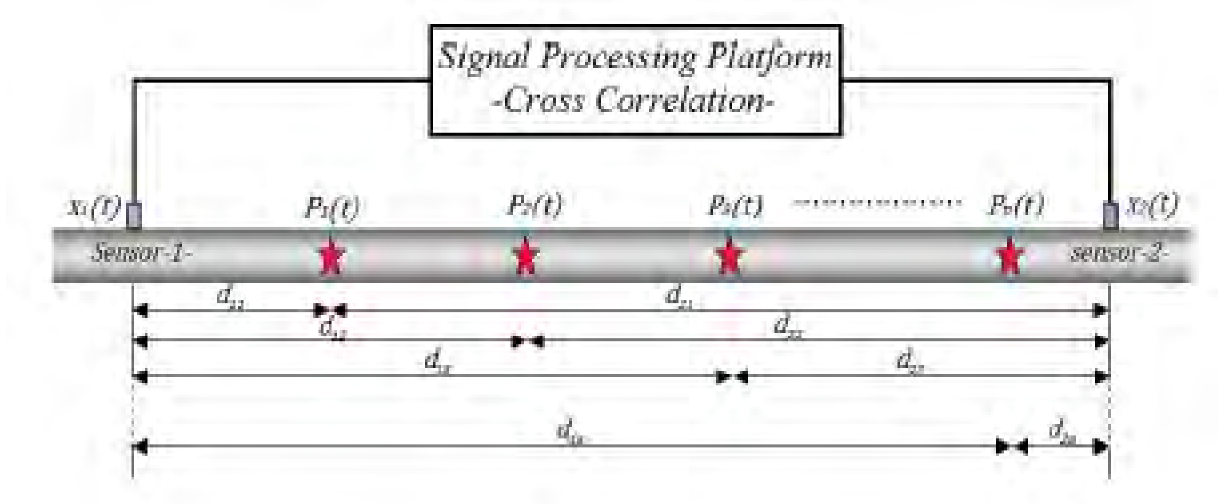

Figure 2.5: Schematic diagram of multi leakage point

Figure 2.5 shows the typical schematic diagram measurement of leakage detection of a buried pipeline. From the figure above, the measurement of signal of leakage with influence from noise can be modeled by two equations [18], [22], [23].

$$x_1(t) = s_1(t) + n_1(t) \tag{2.1}$$

$$x_2(t) = s_2(t) + n_2(t) \tag{2.2}$$

$$s_1(t) = s(t - \tau_1) \tag{2.3}$$

$$s_2(t) = s(t - \tau_2) \tag{2.4}$$

$s_1(t)$ and $s_2(t)$ represent signal for the position of leakage at position 1 and 2, while $n_1(t)$ and $n_2(t)$ are the noise signals measured at positions 1 and 2, and (τ_1, τ_2) are the time delay for $s_1(t)$ and $s_2(t)$ measured at sensor 1 and 2 respectively. Thus, the cross correlation between two signals $x_1(t)$ and $x_2(t)$ is defined by the following equation.

$$C_{x_1x_2} = E[x_1(t)x_2(t+\tau)] \tag{2.5}$$

τ : lag of time, and E[.]: expectation operator.

By assuming the noise generated and leaks signal to be decorrelated then the equation becomes:

$$C_{x_1x_2} = E[x_1(t)x_2(t+\tau)] + E[n_1(t)n_2(t+\tau)] \tag{2.6}$$

Example of noise signal are sound from external factor such as moving car or any event that can be triggered and change the value of signal from the sensor. The equation (2.6) is then divided into two terms, the first part is the present of leak signal's cross correlation and the second term is the noise cross correlation. From the correlation, the expressions for distance d_1 and d_2 as,

$$d_1 = c.\tau_1 \tag{2.7}$$

$$d_2 = c.\tau_2 \tag{2.8}$$

$$d_1 - d_2 = c.(\tau_1 - \tau_2) = c.\tau \tag{2.9}$$

$$d_1 + d_2 = D \tag{2.10}$$

Where D : Distance between sensor 1 and 2

τ_1, τ_2 : Time delay at position 1 and 2

As a result, from equation (2.9), the distance of leakage can be determined as,

$$d_1 = \frac{D+C\tau}{2} \quad (2.11)$$

$$d_2 = \frac{D-C\tau}{2} \quad (2.12)$$

Where d_1 : Distance of leakage from sensor 1

d_2: Distance of leakage from sensor 2

The value of time delay τ can be found at the maximum amplitude of the correlation coefficient. By having the time delay τ and correlation coefficient C, both value can be substitute into equation (2.11) and (2.12) to find the distance of leakage and the sensor.

CHAPTER 3

METHODOLOGY

This chapter describes the project methodology that is used to implement in this project. The methodology of a project is a guideline that will explain about the project flow path. Methodology helps to ensure the project is developed systematically, smoothly and successfully to obtain an excellent and desire result.

3.1 Project Overview

In this subchapter, the flow path for the system is shown with the combination between the component and equipment used as shown in Figure 3.1. Figure 3.2 shows the design layout of the entire setup for this project. In this project, host computer is required as the monitoring system to display real time monitoring pressure of the pipeline and to indicate status of the sensor, and provide leakage alarm occurs in that pipeline. NI myRIO-1900 will be used as the controlling unit for the pressure sensor and integration with LabVIEW.

For this project, LabVIEW software will be used as a base to create a GUI for displaying real time monitoring for indication of pressure value, sensor status and leak alarm.

Wireless data transfer connectivity will be designed using the integration between LabVIEW and NI myRIO-1900 to make the whole setup less hard wire and more towards to be an automated and smart system. From Chapter 2 of literature review, comparison between sensors had been made. Pressure sensor suited the criteria as the sensor to be used to obtain the internal measurement inside the pipeline and as the signal to apply the cross-correlation method to determine the location of leakage.

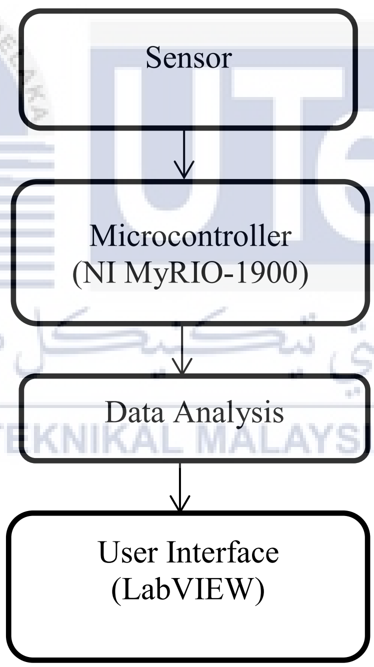

Figure 3.1: Flow of the system

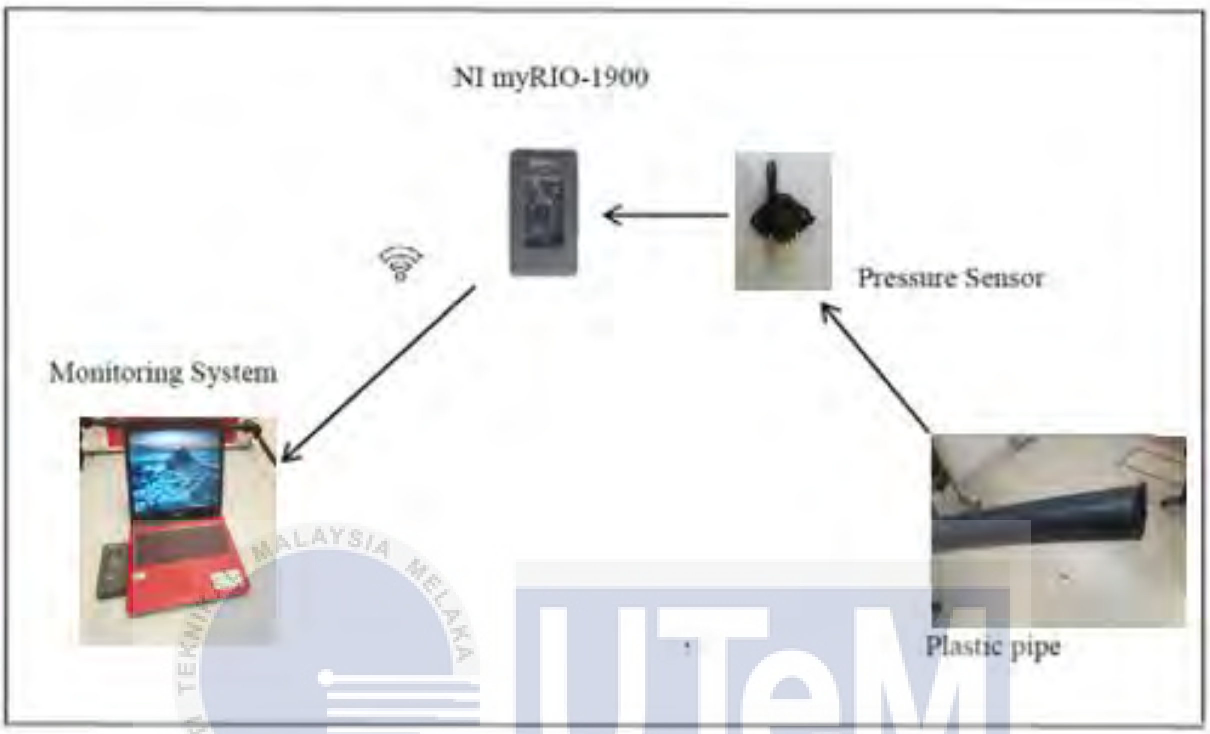

Figure 3.2: Diagram of project layout of whole setup

3.2 Project Working Principle

This project utilizes a 5 m long of HDPE of pipeline with three different pipeline as shown in Figure 3.3 given a variable name of pipeline 1, pipeline 2, and pipeline 3. Pipeline 1 and 3 have the length of two meter while pipeline 2 have the length of 1 m. To simulate leakage, three point are designed along the pipeline known as leak at pipeline 1, pipeline 2 and pipeline 3 respectively as shown in figure below.

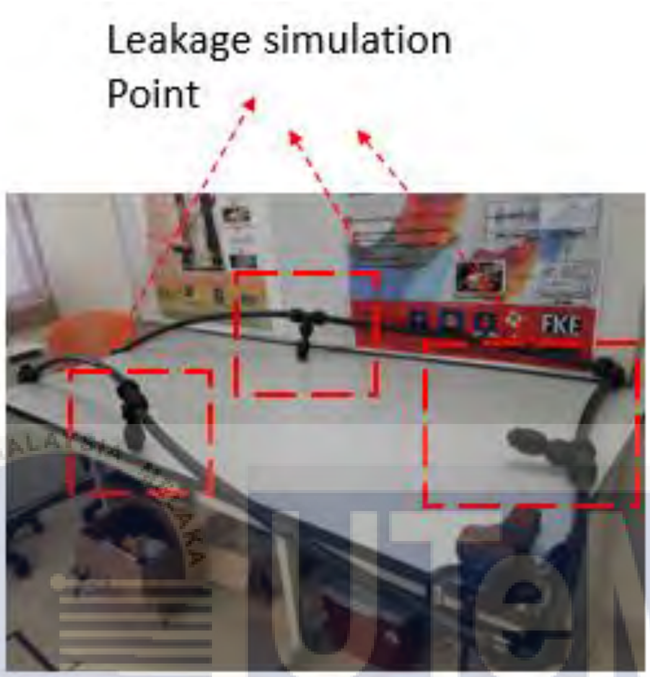

Figure 3.3: Pipeline setup

Two sensors will be installed along the pipeline as shown in Figure 3.3 with measured distance equivalent at five meter apart from each of the sensor. Ideal and leakage condition of pressure sensor value will be determined during the initial experimental testing of the prototype. The amount of analogue value from the sensor during leakage will be used as a threshold value in the graphical programming to differentiate between ideal and leakage condition. A sensor trend will be plot in graph to provide the relationship of pressure sensor reading with distance of leakage. To increase the capability of the system in detecting approximate of leakage, cross correlation techniques is used from two pressure sensor analogue signal to determine the location of the leakage.

Figure 3.4: DC Water Pump

A DC water pump operating at 12 VDC shown in Figure 3.4 will be used to circulate the water throughout the pipeline is used. The water pump capable to provide 840 liters per hour of water and supply water pressure not more than two bar if operating at maximum rated DC voltage. The analogue value from the pressure sensor will be the input to the NI myRIO-1900. The NI myRIO-1900 will transmit the analogue input from the sensors to the LabVIEW. A wireless configuration between NI myRIO-1900 and LabVIEW will be established where the GUI of the real-time pressure data and monitoring system will be display.

Figure 3.5: Project setup between sensor, pipe, NI myRIO-1900 and Host Computer

User could view the current pressure value in each of the pressure sensor reading in the LabVIEW. An alarm indicator will be placed at the front panel of the LabVIEW in which will turn red when the system detects leakage or in any undesirable event such as leakage, sensor malfunction or protection system and it will also indicate which sensor detects the leakage thus pin point the exact location of the leakage. Each of the sensor installed will have an interface indicating the pressure numeric value and the sensor indicator either it is working or malfunctioning. Figure 3.5 represent overall hardware needed in the development

An additional features of microcontroller protection system are developed in this project to prevent from being stolen or damaged and act as anti-tempered device.

3.3 Hardware Development

The hardware development is very important in developing the system prototype which is the water distribution with leakage. The selection of materials such as pressure sensors selection, microcontroller, plastic material dimension (mm) plays a significant role in the hardware development due to the accuracy of the total system.

3.3.1 Sensors selection

Every system required an input to produce a desired output. In this project, pressure sensors as shown in Figure 3.6 are used to obtain the data needed inside the pipeline. In Chapter 2, comparison between pressure and flow rate sensor are reviewed. Pressure sensor have a better accuracy in leak sensitivity and leak location estimation even though the cost is higher compared to flow rate sensor, accuracy attributes is the key performance when it comes in developing a system. Thus, pressure sensors are chosen.

Pressure sensor is an instrument installed with a pressure sensitive element that has the capability to measures the pressure of any non-solid matter material such as gas or liquid. The measured pressure value is then converts into an electrical wave as the output. By using pressure sensors, pressure data can be obtained continuously after analyze threshold value can be used as the input to the whole leak detection system. Table 3.1 shows the specification of the pressure sensor to be used in this project.

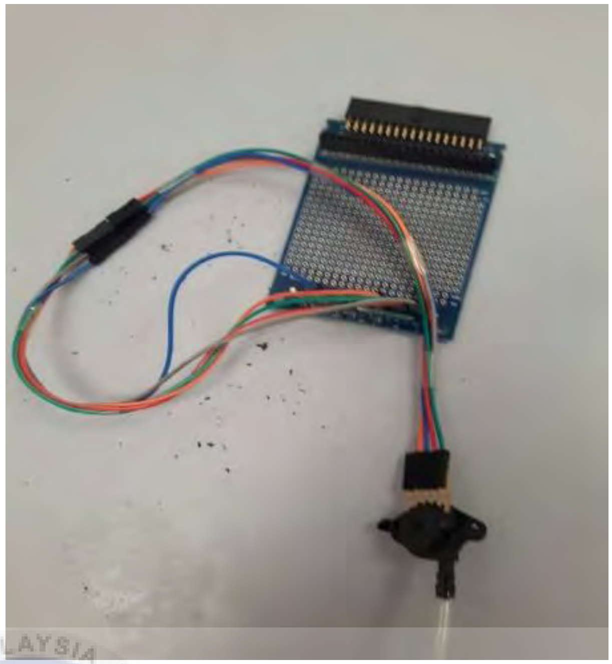

Figure 3.6: Pressure Sensor

Table 3.1: Specifications for Pressure Sensor

Specification	Description
Sensor Output	Voltage
Maximum Operating Pressure	5
Operating Pressure Range	0 to 5 bar
Supply Current	1.5 mA
Pressure Type	Absolute
Voltage Rating	5 VDC

3.3.2 Pipe Selection

This project implements plastic piping material. High density poly-ethene (HDPE) is the most commonly use piping material in distribution piping network and suited to be use in this project. HDPE piping provides long lasting life span as it is widely use in an underground application and in an extreme condition. The nominal diameter of the HDPE pipe also plays a vital role to determine the value of normal operating pressure inside the pipeline during the experimental test. For distribution piping network, maximum of four inch in nominal diameter is usually used, for this project one inch of HDPE was used as shown in Figure 3.7.

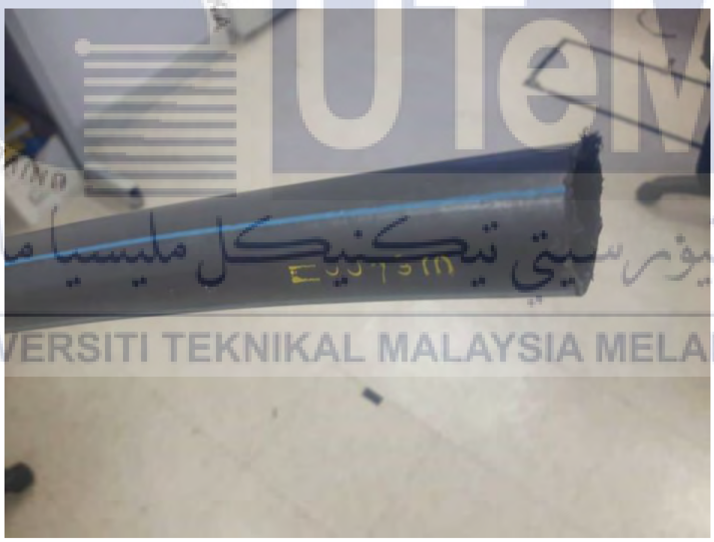

Figure 3.7: HDPE pipe with nominal diameter of one inch

3.3.3 Microcontroller for Data Acquisition

NI myRIO-1900 is a powerful and a unique microcontroller. This device has an embedded dual-core ARM Cortex A9 real time processor combine with the speed of a Field Programmable Gate Array (FPGA) with customizable digital or analogue input and output (I/O) in all in one package. This microcontroller requires LabVIEW to operate and it is a suitable tool to be used in this project due to its unique features such as multiple I/O of analogue or digital and the capabilities to develop wireless network configuration. This microcontroller has 2 different ports for 16 Digital I/O lines, 3 axis accelerometers, capability to develop and connecting a wireless network at 802.11 b, g, n ISM 2.4 GHz 20 MHz and an average of 2.6 watt of power consumption. This device is used to establish the wireless network configurations and the microcontroller. Figure 3.8, Table 3.2 and Figure 3.9 shows the NI myRIO-1900, NI myRIO-1900 specifications and its pin layout diagram respectively.

Figure 3.8: NI myRIO-1900

Table 3.2: Specifications table for NI myRIO-1900

Specifications	Descriptions
Processor	Xilinx Z-7010
Wireless Characteristics	
Radio mode	IEEE 802.11 b, g, n
Frequency Band	ISM 2.4 GHz
Channel Width	20 MHz
Outdoor range	Maximum 150 meters
Analog Input / Output Voltage	0 to 5 V
USB Ports	2
Audio Input	± 2.5 V
Power Output (+5 V power output)	4.75 V to 5.25 V
Maximum Current on each connector (+5 V power output)	100 mA
Power Output (+3.3 V power output)	3.0 V to 3.6 V
Maximum Current on each connector (+3.3 V power output)	150 mA
Power Supply Voltage range	6 VDC to 16 VDC
Maximum power consumption	14 W
Typical idle power consumptions	2.6 W
Ambient Temperature	0 ℃ to 40 ℃
Storage Temperature	-20 ℃ to 70 ℃
Weight	193 g

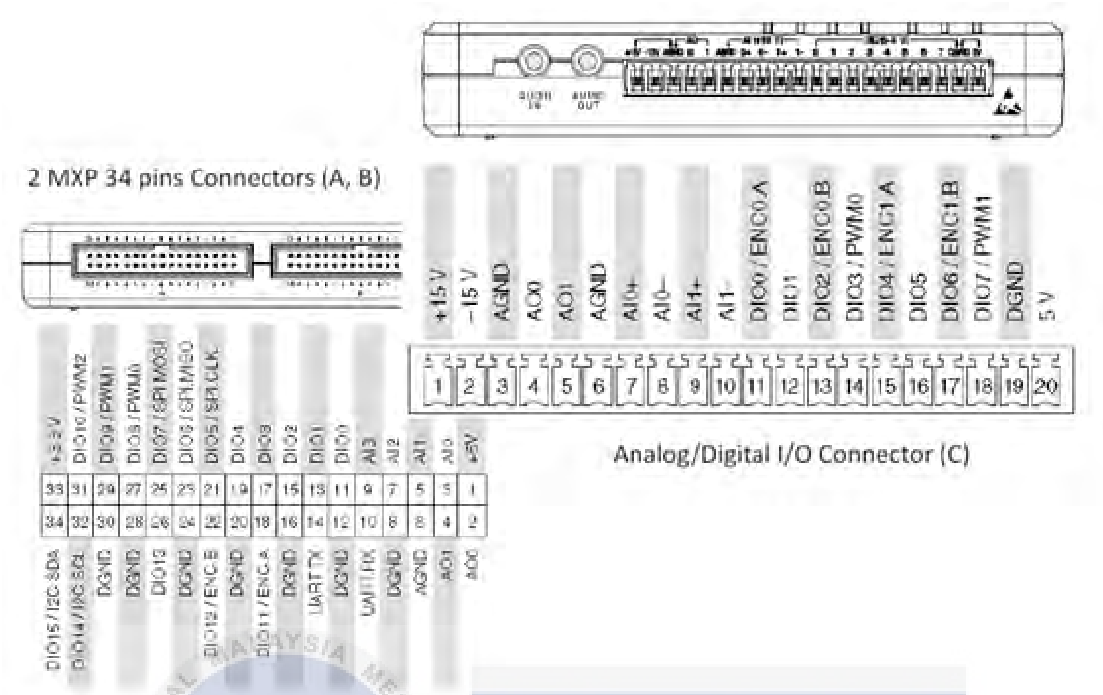

Figure 3.9: NI myRIO-1900 pin layout diagram

3.3.4 Graphical User Interface

Graphical user interface is the device or gadget used to displayed the user desired output. For this project, a host computer installed with LabVIEW software is used to display the output as shown in Figure 3.9. In the host computer, user could see the real-time pressure numerical value, leakage indicator and malfunction indicator. The GUI is designed in tab control as shown in Figure 3.11 to make it user friendly. Figure 3.11 also represent the main pipeline GUI to display the leak location for the pipeline.

Figure 3.10: Host Computer with LabVIEW software

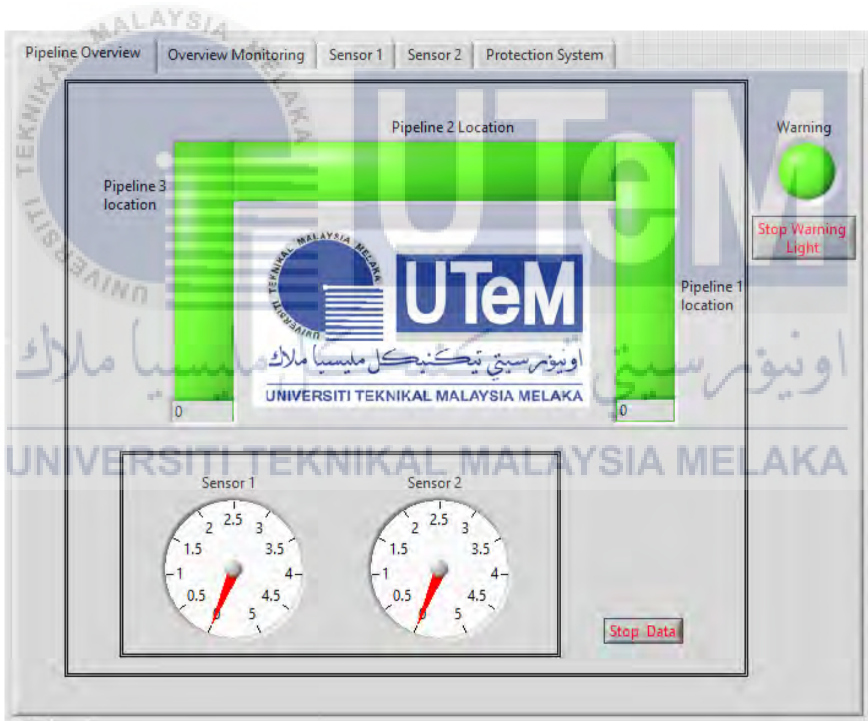

Figure 3.11: Front panel of the pipeline overview GUI in LabVIEW

3.4 Software Development

By using a NI myRIO-1900 microcontroller, the programming is done through LabVIEW graphical programming method. The software development is where data processing take place. The data analysis can be done in LabVIEW software and the data are displayed here. To extract the analogue data in ideal and range of leak location in leakage condition on each sensor reading, block diagram configuration and front panel configuration are constructed for sensor 1 and sensor 2 in LabVIEW are shown in Figure 3.12 and 3.13 respectively

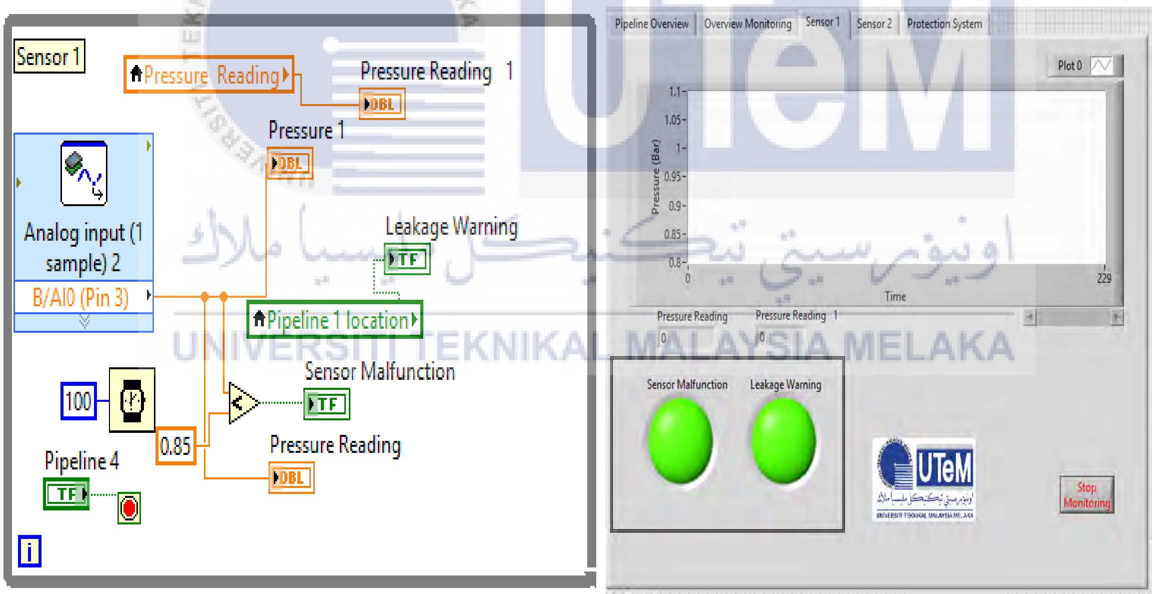

Figure 3.12: Block diagram and front panel configuration in LabVIEW software for pressure sensor 1

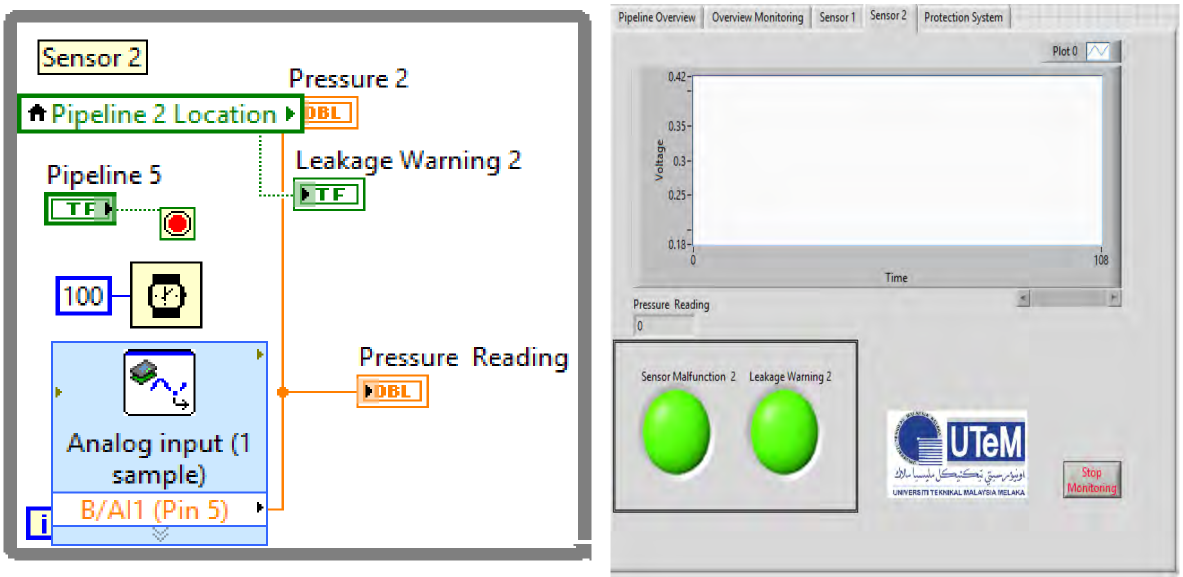

Figure 3.13: Block diagram and front panel configuration in LabVIEW software for pressure sensor 2

After the data had been extracted, cross correlation technique is applied for the signal between two sensors during leakage simulation testing to determine the approximate location of leakage along the pipeline. Figure 3.14 shows the block diagram configuration to apply cross correlation technique. From the chart output of the cross-correlation technique, time delay, τ and the correlation coefficient, C amplitude can be determined. From time delay and correlation coefficient, the distance of leak can be estimated by using following equation formula (2.11) and (2.12)

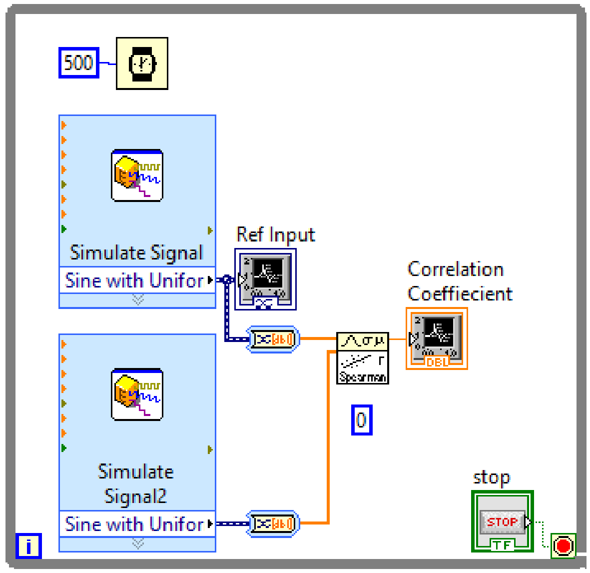

Figure 3.14: Block diagram of cross correlation function

3.5 Wireless Configuration between NI myRIO-1900 and Host Computer

NI myRIO-1900 has the capability to create a wireless configuration between the microcontroller and the host computer to make the system more towards advance technology and less hardwired connection are required. The first step to develop the wireless configuration is as shown in Figure 3.15. To ensure the host computer can connect to the microcontroller, internet protocol address is required. Since NI myRIO-1900 is the host to create the wireless configuration, the host computer must connect to the same IP address as the NI myRIO-1900 as shown in Figure 3.16 to enable connectivity and data transfer.

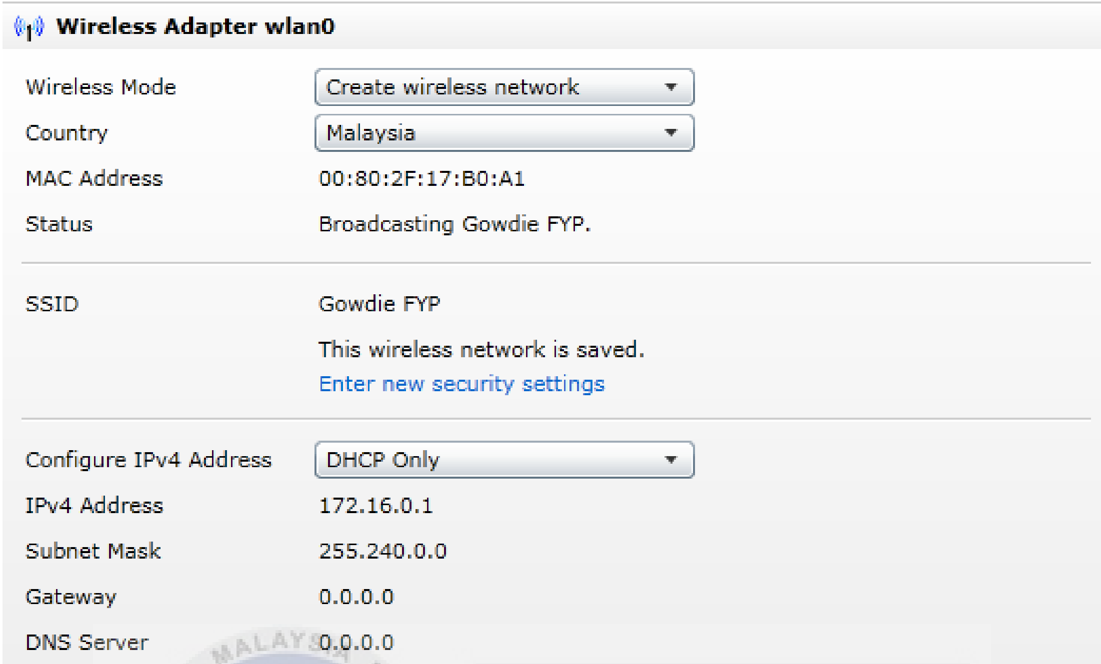

Figure 3.15: Creating A Wireless Network from NI-Max Application Software for NI myRIO-1900

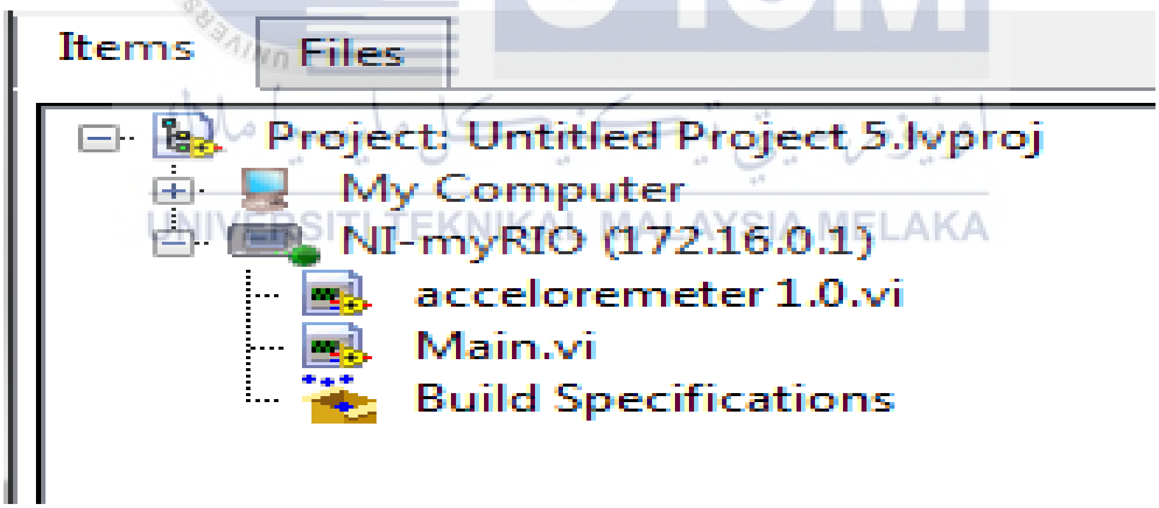

Figure 3.16: Connecting A Wireless Network from NI myRIO-1900 IP To LabVIEW

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the result obtained thru experimental testing is analyzed thoroughly in this chapter to designed the suitable threshold for detecting range of leakage location and to differentiate between ideal and leak condition threshold analogue reading. Cross-correlation technique will be used to validate and determine the exact location of leakage along the pipeline. Thus, a standalone real time monitoring leakage detection system can be developed.

4.1 Statistical Analysis

This part of result is important as it will be a starting based in data collection of pressure sensor reading for ideal and leakage condition. The value obtain will be analyzed to determine the relationship of pressure sensor reading and location of leakage.

4.1.1 Ideal Condition

In ideal condition, the system is considered and assume as there is no leakage occurs along the pipeline. Thus, the water can circulate normally throughout the system.

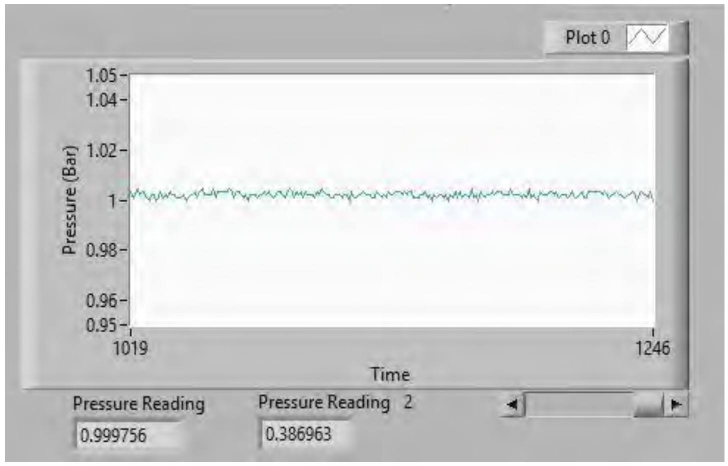

Figure 4.1: Sensor 1 reading in Ideal condition

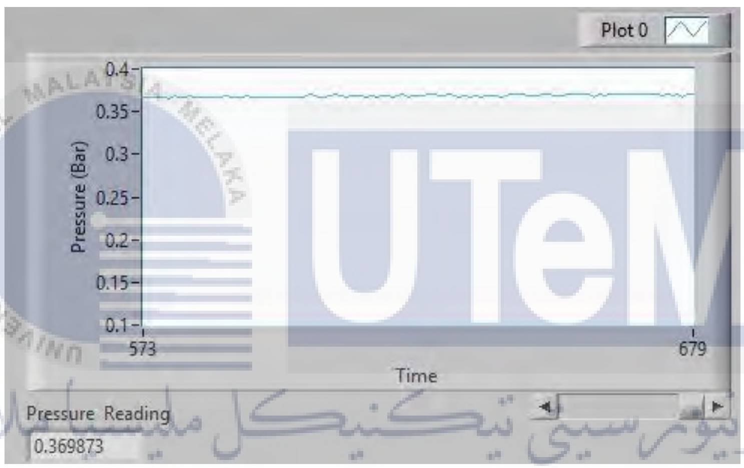

Figure 4.2: Sensor 2 reading in Ideal condition

Figure 4.1 and 4.2 shows the reading of sensor 1 and sensor 2 reading in ideal condition. The experimental testing on data collection for reading of sensor 1 and sensor 2 are done for five minutes. The data is tabulated for every minute in Table 4.1.

Table 4.1: Sensor reading in Ideal condition

Time (Minutes)	Sensor 1 (Voltage)	Sensor 2 (Voltage)
1	0.98	0.41
2	0.98	0.39
3	1.05	0.40
4	0.98	0.39
5	0.99	0.39

$$Average\ Reading\ for\ sensor\ 1 = \frac{0.99 + 0.98 + 1.05 + 0.98 + 0.99}{5}$$

$$Average\ Reading\ for\ sensor\ 2 = \frac{0.41 + 0.39 + 0.40 + 0.39 + 0.39}{5}$$

Table 4.2: Sensor Average, Minimum and Maximum reading

Parameters	Sensor 1 (Voltage)	Sensor 2 (Voltage)
Average reading	1.00	0.39
Minimum reading	0.98	0.39
Maximum reading	1.00	0.41

From the table 4.2, the average reading for ideal condition in sensor 1 is 1.00 V while sensor 2 average reading is 0.39 V. The voltage drop between sensor 1 and sensor 2 can be expected as sensor 1 is located at the starting of the pipeline and near to the water pump. The obvious drop in sensor 2 is due to location of sensor 2 is located at the end of the pipeline, with the distance of five meter apart from the water pump, the value of voltage is drop. From the experimental test, the minimum and maximum reading for sensor 1 is 0.98 V and 1.00 V respectively. While the minimum and maximum reading for sensor 2 is 0.39 V and 0.41 V respectively.

4.1.2 Simulation of Leakage at Pipeline 1

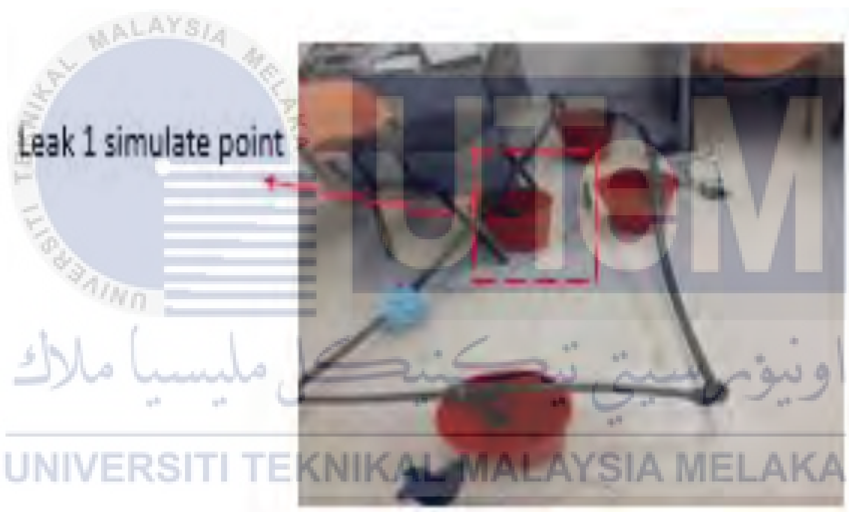

Figure 4.3: Leak 1 simulation point

Figure 4.3 is the location of leak 1 simulation at pipeline 1. The distance of leak location between Sensor 1 is 1 m while the distance between leak location and Sensor 2 is 4 m. Figure 4.4 and 4.5 shows the reading of sensor 1 and sensor 2 reading when leak occurs at pipeline 1. The experimental testing on data collection for reading of sensor 1 and sensor 2 are done for five minutes. The voltage reading is tabulated in Table 4.3.

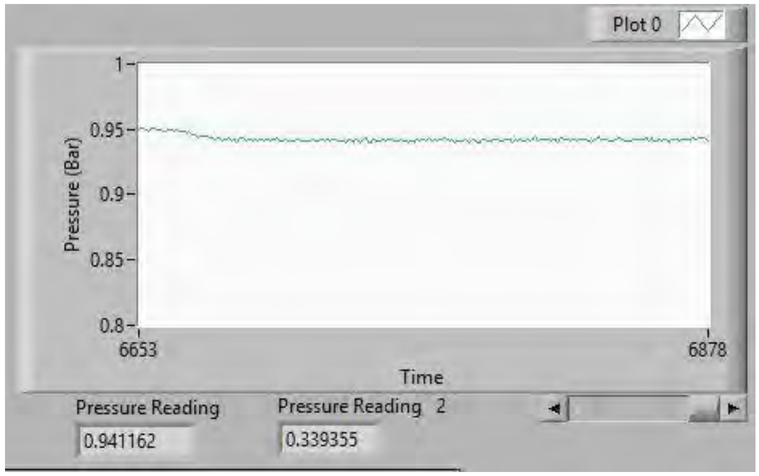

Figure 4.4: Sensor 1 reading for Leak 1 simulation

Figure 4.5: Sensor 2 reading for Leak 1 simulation

Table 4.3: Sensor reading for Leak 1 simulation

Time (Minutes)	Sensor 1 (Voltage)	Sensor 2 (Voltage)
1	0.94	0.33
2	0.95	0.31
3	0.92	0.31
4	0.94	0.32
5	0.92	0.31

$$Average\ Reading\ for\ sensor\ 1 = \frac{0.94 + 0.95 + 0.92 + 0.94 + 0.92}{5}$$

$$Average\ Reading\ for\ sensor\ 2 = \frac{0.33 + 0.31 + 0.31 + 0.32 + 0.31}{5}$$

Table 4.4: Sensor Average, Minimum and Maximum reading for Leak 1 Simulation

Parameters	Sensor 1 (Voltage)	Sensor 2 (Voltage)
Average reading	0.93	0.32
Minimum reading	0.92	0.31
Maximum reading	0.95	0.33

From the Table 4.4 the average reading for leak condition in pipeline 1 in sensor 1 is 0.93 V while sensor 2 average reading is 0.32 V. There is a slight drop for both pressure sensor reading from its ideal voltage value reading. The slight drop in voltage reading for both sensor can be expected as water are flowing out from the simulation of leakage along the pipeline 1. From the experimental test, the minimum and maximum reading for sensor 1 is 0.92 V and 0.95 V respectively. While the minimum and maximum reading for sensor 2 is 0.31 V and 0.33 V respectively.

4.1.3 Simulation of Leakage at Pipeline 2

Figure 4.6: Leak 2 simulation point

Figure 4.6 is the location of leak 2 simulation at pipeline 2. The distance of leak location between sensor 1 is one meter while the distance between leak location and sensor 2 is 2.5 meter. Figure 4.7 and 4.8 shows the reading of sensor 1 and sensor 2 reading when leak at pipeline 2 is simulated. The experimental testing on data collection for reading of sensor 1 and sensor 2 are done for five minutes. The data is tabulated in Table 4.5

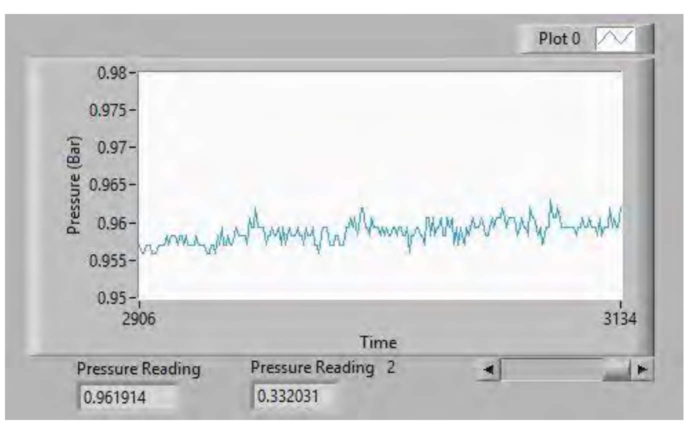

Figure 4.7: Sensor 1 reading for Leak 2 simulation

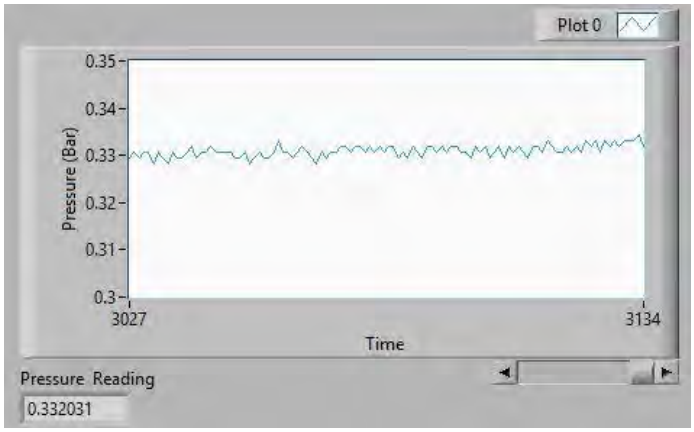

Figure 4.8: Sensor 2 reading for Leak 2 simulation

Table 4.5: Sensor reading for Leak 2 simulation

Time (Minutes)	Sensor 1 (Voltage)	Sensor 2 (Voltage)
1	0.95	0.34
2	0.96	0.33
3	0.97	0.33
4	0.96	0.34
5	0.96	0.32

$$Average\ Reading\ for\ sensor\ 1 = \frac{0.95 + 0.96 + 0.97 + 0.96 + 0.96}{5}$$

$$Average\ Reading\ for\ sensor\ 2 = \frac{0.34 + 0.33 + 0.33 + 0.34 + 0.32}{5}$$

Table 4.6: Sensor Average, Minimum and Maximum reading for Leak 2 simulation

Parameters	Sensor 1 (Voltage)	Sensor 2 (Voltage)
Average reading	0.96	0.33
Minimum reading	0.95	0.32
Maximum reading	0.97	0.34

From the Table 4.6 above, the average reading for leak condition in pipeline 2 in sensor 1 is 0.95 V while sensor 2 average reading is 0.34 V. There is a slight drop at 0.04 V and 0.06 V for sensor 1 and sensor 2 respectively from its ideal condition value reading. There is also different in voltage reading compared when leak 1 is simulated. Simulation of leak at pipeline 2 shows smaller value compared to leak 1 simulation. This is associated with the distance of leak point to the sensor. Since the distance of leak is 2.5 m from both sensor 1 and 2, the water pressure will take a longer time to produce same amount of reading as in during the simulation of leak at pipeline1. With the same flow rate apply for all of the experimental testing, reader could validate the hypothesis of the longer the distance of leak source to the sensor, the lower the voltage reading obtain by the sensor. From the experimental test, the minimum and maximum reading for sensor 1 is 0.95 V and 0.97 V respectively. While the minimum and maximum reading for sensor 2 is 0.32 V and 0.34 V respectively.

4.1.4 Simulation of Leakage at Pipeline 3

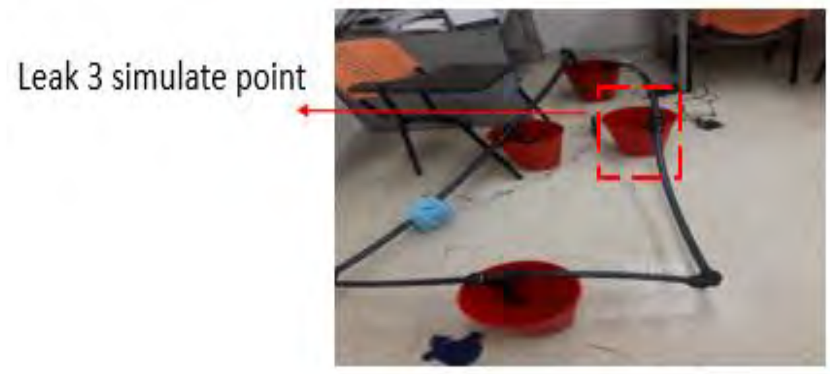

Figure 4.9: Leak 3 simulation point

Figure 4.9 is the location of leak 3 simulate at pipeline 3. The distance of leak location between sensor 1 is 3.5 m while the distance between leak location and sensor 2 is 0.5 m. Figure 4.10 and 4.11 shows the reading of sensor 1 and sensor 2 reading when leak at pipeline 2 is simulated. The experimental testing on data collection for reading of sensor 1 and sensor 2 are done for five minutes. The data is tabulated in Table 4.7

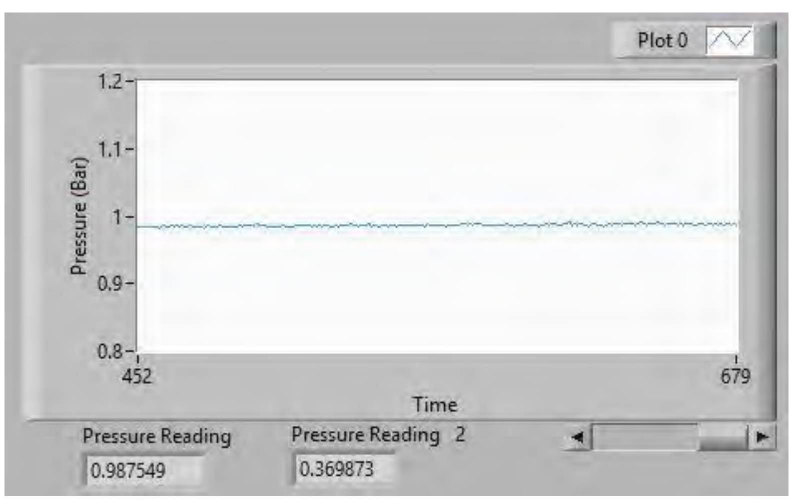

Figure 4.10: Sensor 1 reading for Leak 3 simulation

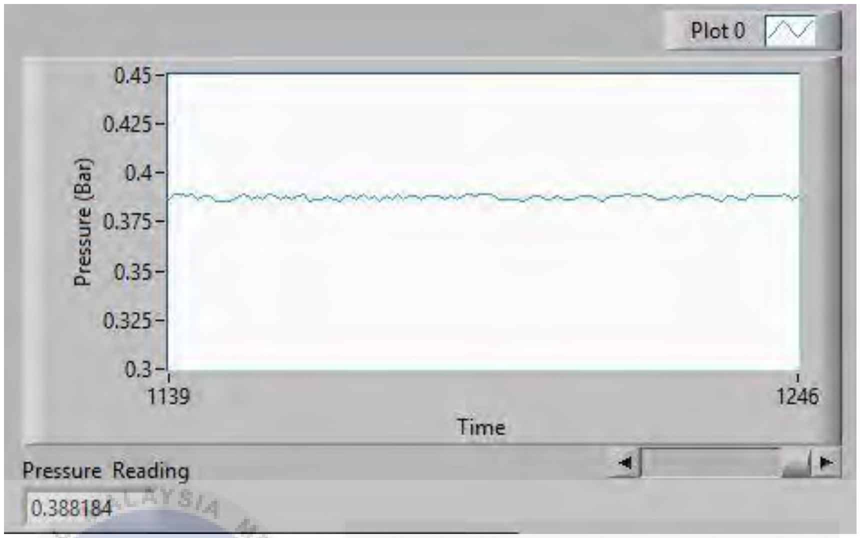

Figure 4.11: Sensor 2 reading for Leak 3 simulation

Table 4.7: Sensor reading for Leak 3 simulation

Time (Minutes)	Sensor 1 (Voltage)	Sensor 2 (Voltage)
1	0.99	0.36
2	0.97	0.35
3	0.98	0.37
4	0.97	0.36
5	0.97	0.36

$$Average\ Reading\ for\ sensor\ 1 = \frac{0.99 + 0.97 + 0.98 + 0.97 + 0.97}{5}$$

$$Average\ Reading\ for\ sensor\ 2 = \frac{0.36 + 0.35 + 0.37 + 0.36 + 0.36}{5}$$

Table 4.8: Sensor Average, Minimum and Maximum reading

Parameters	Sensor 1 (Voltage)	Sensor 2 (Voltage)
Average reading	0.98	0.36
Minimum reading	0.97	0.35
Maximum reading	0.99	0.37

From the Table 4.8, the average reading for leak condition in pipeline 3 in sensor 1 is 0.98 V while sensor 2 average reading is 0.36 V. There is a slight drop at 0.02 V and 0.03 V for sensor 1 and sensor 2 respectively from its ideal pressure value reading. The reading from Table 4.8 also differs during the experimental testing on leak at pipeline 1 and pipeline 2 simulation. Reading obtain for simulation of leak at pipeline 3 shows more smaller reading compared to the other two experiment. As discuss on 4.1.3, this is due to the distance of leakage to the sensor. From the experimental test, the minimum and maximum reading for sensor 1 is 0.97 V and 0.99 V respectively. While the minimum and maximum reading for sensor 2 is 0.35 V and 0.37 V respectively.

4.1.5 Summary of Average Value for Ideal Condition and Leakage Condition

Based on the statistical analysis done in 4.1.1 till 4.1.4, an average reading is determined. The data is crucial to developed a logical programming in the LabVIEW software development to differentiate the characteristics of ideal and leak location. A summarized table of average sensor reading for both sensor 1 and sensor 2 are tabulated in Table 4.9 below. As shown in Figure 4.12 and Figure 4.13, reader could see the trend of relationship graph between voltage and distance for sensor 1 and sensor 2 respectively. For sensor 1 graph, the relationship between voltage and distance is directly proportional. Based on the trend in Figure 4.12, as the leakage location keep on increasing, the pressure sensor reading will also increase and when the distance of leakage is 5 meter, the voltage reading will approach 1.00 V. This is acceptable as at 5 meter, there are no leak occurs due to the length of this pipeline prototype is 5-meter long. For sensor 2 graph, the trend Figure 4.13 shows voltage increase exponentially when the distance location of leakage increase. Both graph produce a directly proportional relationship between voltage and distance.

Table 4.9: Summary of sensor reading

Parameters	Sensor 1 (Voltage)	Sensor 2 (Voltage)
Ideal Condition	1.00	0.39
Leak at Pipeline 1	0.93	0.32
Leak at Pipeline 2	0.96	0.33
Leak at Pipeline 3	0.98	0.36

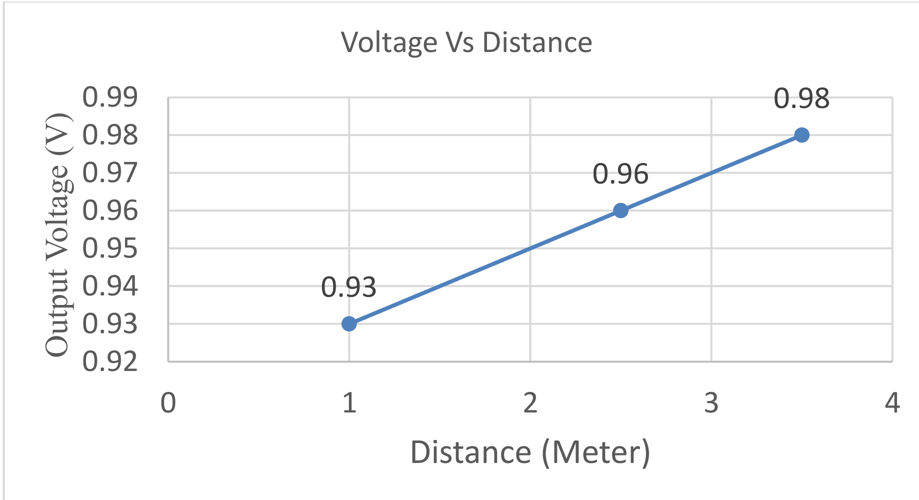

Figure 4.12: Sensor 1 relationship graph for voltage and distance

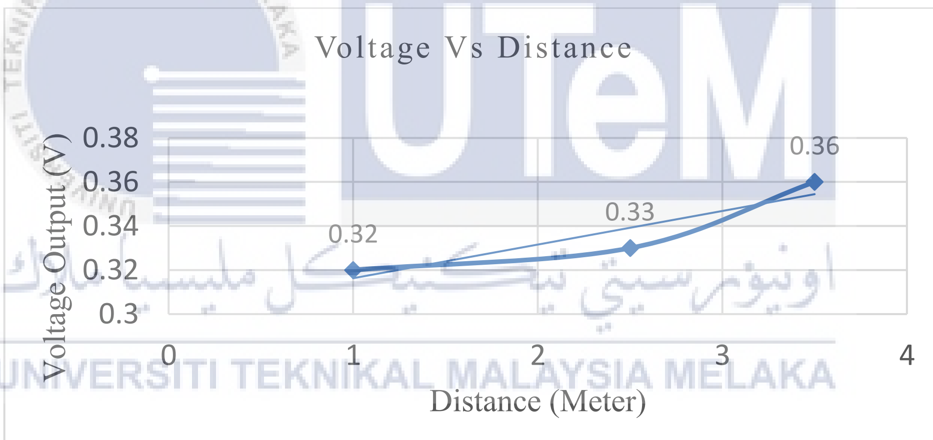

Figure 4.13: Sensor 2 relationship graph for voltage and distance

4.2 Cross Correlation Technique

In this subchapter, cross-correlation technique is applied to obtain the estimation of leak location. It is done by correlating two signal and find the time taken for both signal to aligned together. The time taken is also known as the time delay. From the time delay, the correlation coefficient could be found and the distance between sensor and location of leak can be determined.

4.2.1 Cross Correlation at Leak 1

Figure 4.14 shows the correlation coefficient for sensor 1 and sensor 2 signals with time taken set to 3 seconds for each signal which leads equivalent to 6 seconds of correlation time in LabVIEW software. From Figure 4.14 and Table 4.10 the estimated time delay is 2.3 seconds. The correlation coefficient amplitude during time delay 2.3 seconds is 0.89. The distance of leak between sensor 1 and sensor 2 can be calculated by inserting value of time delay and correlation coefficient into following formula.

$$d_1 = \frac{D+C\tau}{2} \qquad d_2 = \frac{D-C\tau}{2}$$

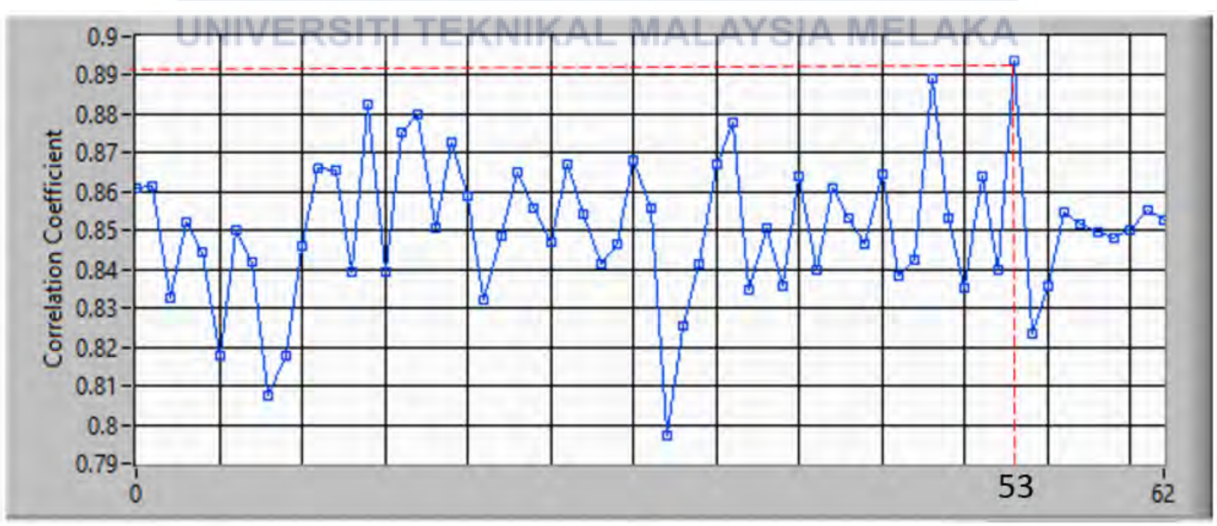

Figure 4.14: Cross correlation signal at Leak 1

Table 4.10: Time delay and correlation coefficient at Leak 1

Parameters	Value
Time delay (s)	2.3
Correlation Coefficient	0.89

Table 4.11: Cross correlation estimation distance at Leak 1

Parameters	Measured Leak Distance, meter	Cross correlation estimation distance, meter	Error (%)
d_1	1	1.48	9.6
d_2	4	3.60	8

Based on the Table 4.11, both d_1 and d_2 gave an error for the estimation distance which are 9.6 % and 8 % error respectively. The measured distance between sensor 1 and leakage location is 1 m but the estimation leak location via cross correlation give 1.48 m while the measured distance between sensor 2 and leakage location is 4 m, but the estimation distance is 3.60 m. The amount of error displayed in Table 4.11 is not significant thus the value can be acceptable since there are also elbow joint are present in the construction of the pipeline that might interrupt the pressure reading. The overall equation of cross correlation discussed in subchapter 2.5.1 are as follows:

$$C_{x_1x_2} = E[x_1(t)x_2(t+\tau)] + E[n_1(t)n_2(t+\tau)] \quad (2.6)$$

Equation (2.6) considered the value of noise generated and this technique are mostly applied in a straight-line pipeline. Since there are also elbow joint present along prototype pipeline 2 that might interrupt the ideal correlation signal, it also can be considered as the noise signal generated $n_1(t)$ and $n_2(t)$. In this project, the value of noise signal generated is neglected. Thus, the amount of error (%) present in the estimation of leakage distance can be accepted if the noise signal is considered.

4.2.2 Cross Correlation at Leak 2

From Figure 4.15 and Table 4.12 below, the estimated time delay for both signal to become aligned is 0.9 seconds. The correlation coefficient during time delay 0.9 seconds is 0.89.

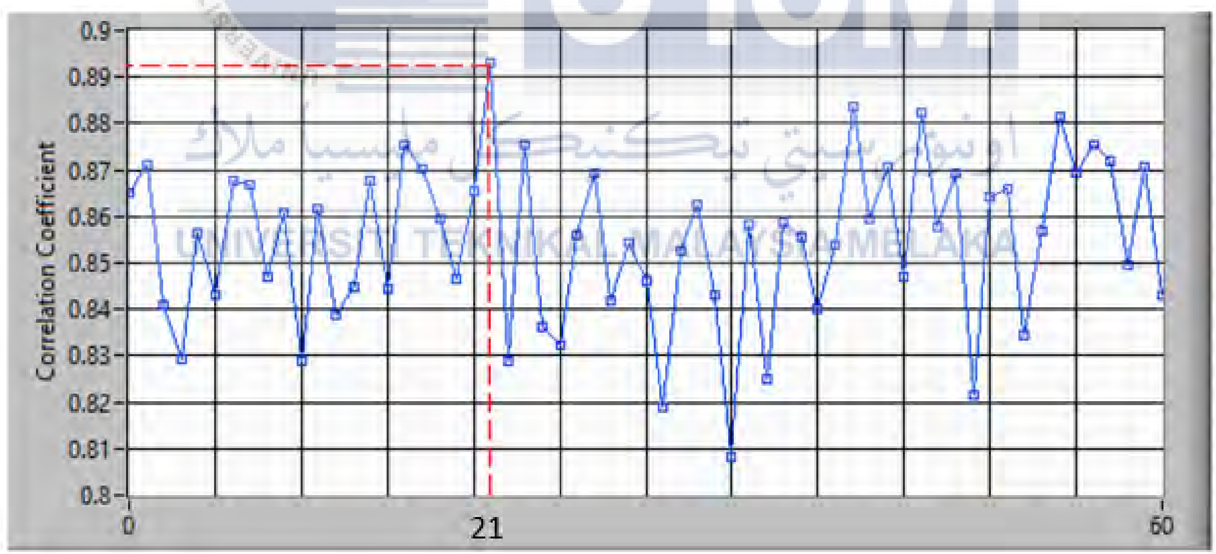

Figure 4.15: Cross correlation signal at Leak 2

Table 4.12: Time delay and correlation coefficient at Leak 2

Parameters	Value
Time delay (s)	0.9
Correlation Coefficient	0.89

Table 4.13: Cross correlation estimation distance at Leak 2

Parameters	Measured Leak Distance, meter	Cross correlation estimation distance, meter	Error (%)
d_1	3	2.90	2
d_2	2	2.01	0.2

From the Table 4.13, both cross correlation estimation distance produce error of 2% for distance between leakage and sensor 1 and 0.2% of error between leakage location and sensor 2. Both error is in small percentage which are 2% and 0.2% respectively for d_1 and d_2. The error might be due to measurement error during taking the measurement for the distance of leakage from the sensor as students use measuring tape and since the HDPE is not completely in straight line, some measurement error might occur during measurement of length of pipeline process. Reader also notice that the during the correlation of signal at Leak 2, the amount of error produce is much smaller with only 2 % maximum error compared to correlation of signal at Leak 1 with maximum error produce up to 9.6 %. As explained in 4.2.1, noise signal plays a significant role in equation (2.6)

$$C_{x_1x_2} = E[x_1(t)x_2(t+\tau)] + E[n_1(t)n_2(t+\tau)] \qquad (2.6)$$

The location for Leak 2 is at pipeline 2 near with the elbow joint. The small error produce could be related to location of leak which are near to the elbow joint and since the elbow joint discussed in 4.2.1 is the noise signal. In this case with small amount of error produce, noise signal could be represented as below by removing the noise signal from equation (2.6):

$$n_2(t) = n_1(t) = 0$$

4.2.3 Cross Correlation at Leak 3

From Figure 4.16 and Table 4.14, the estimated time delay for both signal to become aligned is 2.5 seconds. The correlation coefficient during time delay 2.5 seconds is 0.88.

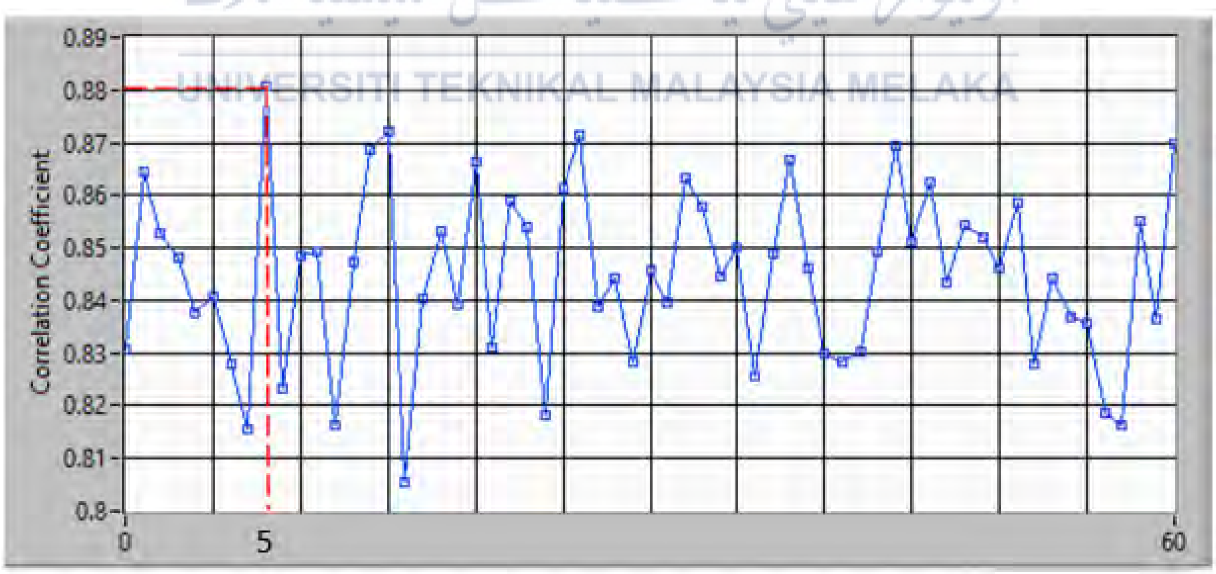

Figure 4.16: Cross correlation signal at Leak 3

Table 4.14: Time delay and correlation coefficient at Leak 3

Parameters	Value
Time delay (s)	2.5
Correlation Coefficient	0.88

Table 4.15: Cross correlation estimation distance at Leak 3

Parameters	Measured Leak Distance, meter	Cross correlation estimation distance, meter	Error (%)
d_1	4	3.60	8
d_2	1	1.40	8

From the Table 4.15, both cross correlation estimation distance give error of 8% for distance between each sensor and leakage location. The measure distance of leak location for d_1 is 4 meter, the estimation leak location result was 3.6 meter. Slight error of 8% was found from measured distance. While, for d_2 the measured distance of leak location is 1 meter and the result from estimation of leak location was 1.4 meter. Same percentage leak location error was found that is 8%. Based on discussion on 4.2.1 and 4.2.2, it can be concluded that, error produce at leak 1 and leak 3 simulation point is larger compared to leak 2. Simulation of Leak 2 is small due to location of elbow joint while leak at pipeline 1 and pipeline 3 does not considered the noise signal generated. Thus, the implementation of cross correlation technique in this project can be accepted and overall equation of cross correlation (2.6) can be applied throughout this project.

4.3 Protection System Test for Microcontroller

The test is done by using the accelerometer sensor embedded inside NI myRIO-1900. Since accelerometer is based on three dimensions direction which is x direction, y direction and z direction. It is suitable to be used as the sensor in the protection system when any sudden change in direction occurs. The microcontroller is connected wirelessly to the LabVIEW during this test. The microcontroller initial position is in vertical position. In term of the microcontroller initial direction of x, y and z direction is as shown in Table 4.16 and Figure 4.17.

The initial value of position of the microcontroller is used as the threshold value of ideal position for the microcontroller. Sudden change in each of the direction will trigger an indicator as shown in Figure 4.18, Figure 4.19 and Figure 4.20.

Table 4.16 Initial Value of Microcontroller in x, y and z (vertical position)

Dimension	Value
x	0
y	0
z	1

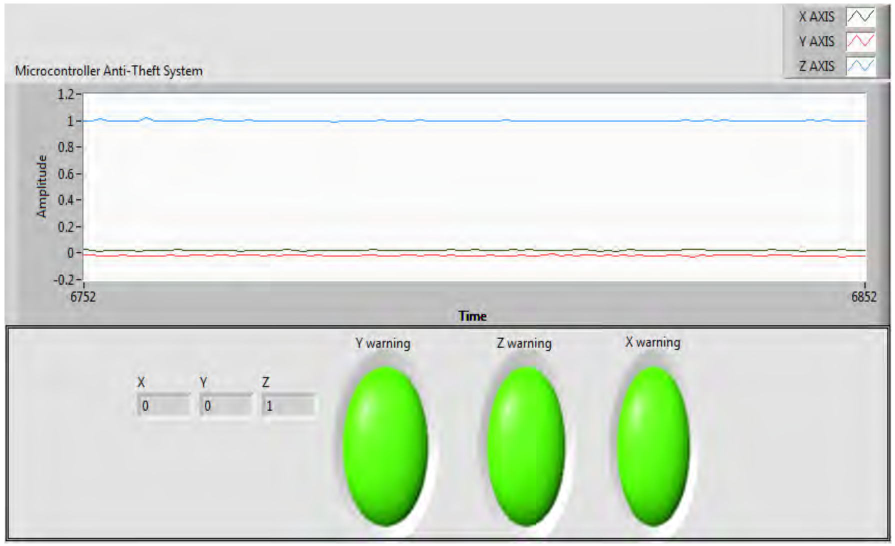

Figure 4.17: Initial value for microcontroller position in x, y and z direction

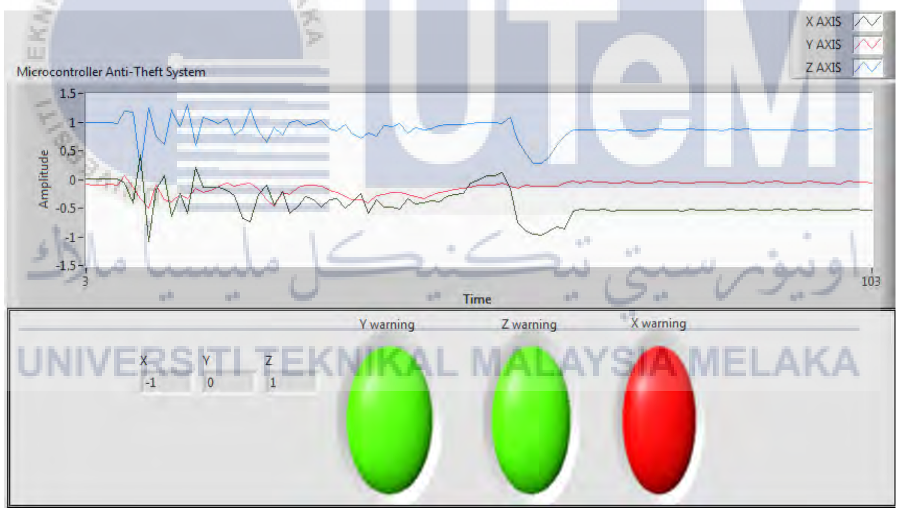

Figure 4.18: Indicator test during altered in X-direction

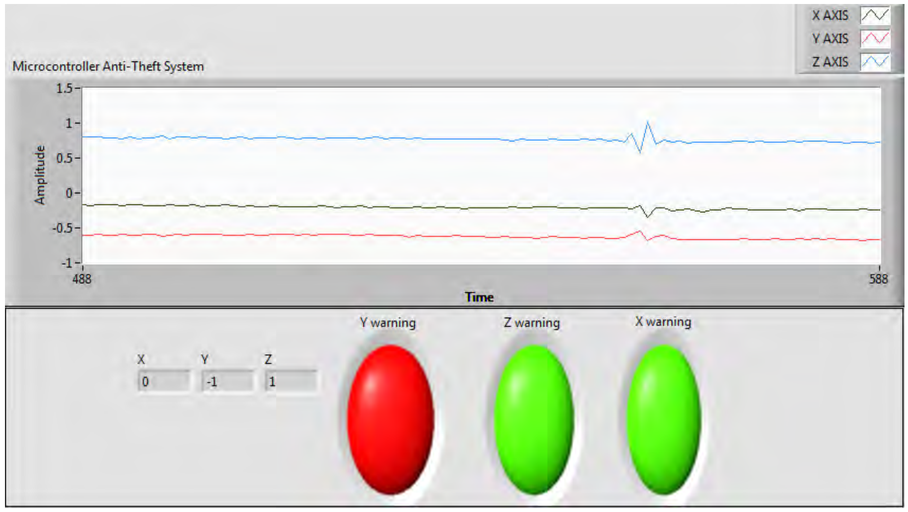

Figure 4.19: Indicator test during altered Y-direction

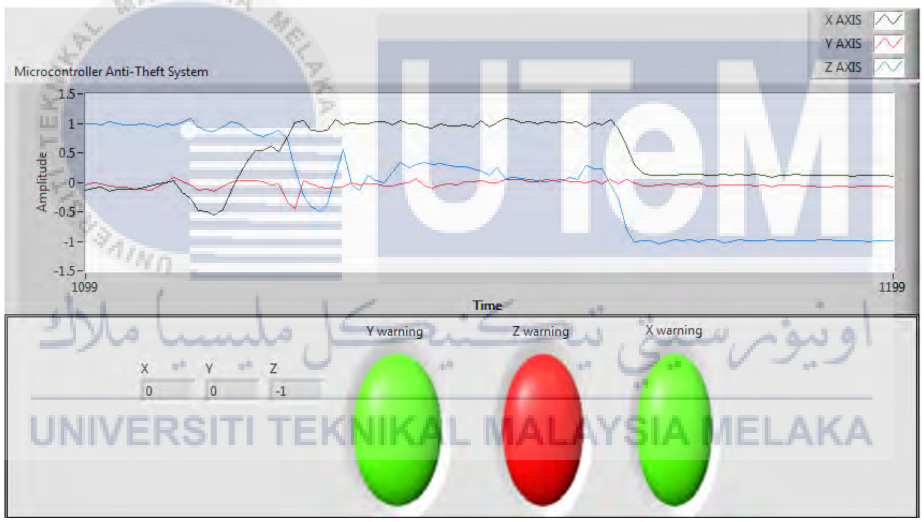

Figure 4.20: Indicator test during altered in Z-direction

CHAPTER 5

CONCLUSION
AND RECOMMENDATIONS FOR FUTURE WORK

By setting the desired threshold in the software development, the total system able to detect and differentiate ideal and leakage condition of pipeline. The distance of leakage is validated by applying cross correlation technique between the signal from sensor 1 and sensor 2 to obtain the distance of leakage along the pipeline. From the correlation of two different signal, the distance of leakage can be determined. There are slight error present in term of distance in detecting the location of the leakage for each of the simulated leakage by using cross correlation technique, but the error is below 10% and it is acceptable. From the experimental test, this project is a success as it fulfills all three objectives mention above and the output result in the monitoring system is the desirable result.

For future work, it is recommended to test this project in a longer pipeline to increase the capability of this system. Different kind of sensor such as flow sensor or velocimeter can be implemented as in this project the usage pressure sensor only gives a slight different in pressure drop due to the input pressure is not high enough and installing a pressure sensor made the testing to be called destructive testing (DT) which are not convenient for a pipeline. Other leak detection method such as acoustic method could be implemented in this project.

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Appendix A

Gantt chart for Final Year Project 1

WEEK / TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Title Selection 1.Discuss with supervisor	■													
PSM 1 Briefing		■												
Literature Review														
1.Research on water distribution network pipeline			■	■										
2.Study on Hardware base method leak detection					■									
3.Study on Software base method						■								
4.Study on Cross Correlation Technique						■								
Project Simulation														
1.Finding suitable software and microcontroller to use						■	■							
2.Design a simulation test for one pressure sensor							■	■	■					
3.Design a simulation test for protection system and wireless network configuration								■	■	■				
Progress report Writing		■	■	■	■	■	■	■	■	■	■	■		
Report Submission														
1.Draft Progress Report													■	
2.Final Progress Report														■
PSM 1 Seminar														■

Appendix B

Gantt chart for Final Year Project 2

TASK \ WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Design & Development of Software (LabVIEW)															
1.Design the GUI and block diagram for pipeline															
2.Design block diagram in LabVIEW to apply cross correlation technique															
3.Design the algorithm for ideal and leak condition															
Design & Development of Hardware															
1.Design project setup layout															
2.Install sensor at pipeline															
3.Build prototype															
Experimental Testing															
1.Pressure data collection															
2.Testing and troubleshoot total system															
Report Submission															
1.Draft Progress Report															
2.Final Progress Report															
PSM 2 Seminar															

Appendix C

Project Flow Chart