Faculty of Electrical Engineering

DEVELOPMENT OF PID-PLC BASED CONTROL STRATEGY FOR WINDER SYSTEM

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DEVELOPMENT OF PID-PLC BASED CONTROL STRATEGY FOR WINDER SYSTEM

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in fulfillment of the requirements for the Bachelor of Electrical
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DECLARATION

I declare that this thesis entitled "Development of PID-PLC Based Control Strategy for Winder System" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NURKHURATUL AINI BINTI KAMARUDZAMAN

Date : ....

APPROVAL

“ I hereby declare that I have read this report entitle Development of PID-PLC Based Control Strategy for Winder System and in my opinion this 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 : EN MOHAMAD RIDUWAN BIN MD NAWAWI

Date : ………………………………………………………

ABSTRACT

This paper will presents the mathematical model and improvement for winder system by adding the Proportional Intergral Derivative (PID) controller. Nowadays, winder system is commonly used as transporting system in production of textile, paper, metal, wire and more flexible material. Currently most of winder system using Programmable Logic Controller (PLC), tension observer controller, and others controller. The main goal of this project is to develop PID controller system into winder tension system to make the system more stable and consistent when running. Winder system move according to instruction given by PLC ladder diagram. In this paper, the PID gain parameters are tunned by heuristic aproach. The mathematical modeling of the system is established based on the tension control, speed of motor and other elements related to the system. Therefore, fabrication of lab-scale winder tension system that used in this project which is controlled by the MIDORI Green Pot Precision sensor using the PID algorithm system in PLC based system as the controller. The sensor relocated with the pendulum dancer and give the signal that control the speed of the motor based on the pendulum dancer. If the pendulum dancer moves upward, the sensor will give the signal to the PLC to speed up the speed of the motor. In PID system, the measurement that will be consider is proportional, integral and derivative. In this paper, Micro Box used to collect data from plant through MATLAB software. In experimental part, several experiment was done according to setup condition. Due to experimental results after implement PID, the optimum range for position of pendulum dancer is starting 60° to 85°. At the end of project give the results after implement PID controller, the system become more consistent and the problem of loosen of wire is overcome by that.

ABSTRAK

Kertas kerja ini akan membentangkan model matematik dan penambahbaikan untuk sistem penggulungan. Pada masa kini, sistem penggulungan kebiasaannya digunakan sebagai sistem pengangkutan dalam pengeluaran tekstil, kertas, logam, dawai dan bahan yang lebih fleksibel. Pada masa ini kebanyakan sistem penggulungan menggunakan 'Programmable Logic Controller (PLC)', pengawal ketegangan pemerhati, dan lain-lain pengawal. Matlamat utama projek ini adalah untuk membangunkan sistem pengawal PID ke dalam sistem penggulungan untuk membuat sistem ini lebih stabil dan konsisten. Sistem penggulungan ini dikendalikan mengikut arahan yang diberikan oleh rajah tetangga PLC. Dalam kertas ini, kaedah penalaan parameter yang akan digunakan adalah cuba dan kaedah kesilapan untuk pengawal PID. Pemodelan matematik sistem itu ditubuhkan berdasarkan kawalan ketegangan, kelajuan motor dan unsur-unsur lain yang berkaitan dengan sistem. Oleh itu, fabrikasi sistem winder ketegangan yang digunakan dalam projek ini yang dikawal oleh MIDORI Green sensor Pot Precision menggunakan sistem algoritma PID dalam sistem berasaskan PLC sebagai pengawal. Alat pengesan dikawal oleh penari bandul dan memberi isyarat yang mengawal kelajuan motor berdasarkan penari bandul. Jika penari bandul bergerak ke atas, sensor akan memberikan isyarat kepada PLC untuk mempercepatkan kelajuan motor. Dalam sistem PID, pengukuran yang akan dipertimbangkan adalah berkadar, penting dan derivatif. Dalam kertas ini, Micro Box digunakan untuk mengumpul data dari sistem melalui perisian MATLAB. Dalam bahagian eksperimen, beberapa percubaan telah dilakukan mengikut keadaan persediaan. Daripada keputusan ujikaji selepas melaksanakan PID, julat optimum untuk kedudukan penari bandul bermula 60 ° hingga 85 °.Pada akhir projek memberi keputusan selepas melaksanakan pengawal PID, sistem menjadi lebih konsisten dan masalah melonggarkan wayar diatasi dengan itu.

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Special thanks to all my peers, beloved parents my mother, Puan Norlaili Binti Dollah and my father, Encik Kamarudzaman Bin Mohd Yasin also my siblings for their moral support to me in completing this project until end. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

DEDICATION

I dedicate my dissertation work to my family and many friends. To my beloved mother Puan Norlaili Binti Dollah, my beloved father En Kamarudzaman Bin Mohd Yasin, my sister Norhaslinda, my elder brother Mohammad Shahrol Azrin, my younger brother Muhammad Shahrul Azri, my brother-in-law, my sister-in-law and my lovest nephews that always support me to finish my degree. They always gives me motivation, money, and quality family time when I back home. Thank you so much for all your effort and hope we can always support and love each others till the end our lives. Aaminn.

I also dedicate this dissertation to my many friends who have supported me throughout the process. I will always appreciate all they have done, especially my classmates BEKC, housemates, my close friends and also my juniors to give supportive to me to finish this project.

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LIST OF SYMBOLS

M_d	-	Braking torque acting on unwinding roller
ω	-	Angular velocity of the unwinding roll
V	-	Linear velocity of wire
D	-	Diameter of unwinding rolls
D_0	-	Roll's diameter
b	-	Roll width
h	-	Roll thickness (thickness of wire)
T	-	Roll tension
M	-	Roll quality
J	-	Inertia of unwinding roll
J_k	-	Inertia of wire on the unwinding roll
J_o	-	Inertia of core shaft of unwinding roll
B_f	-	Damping coefficient
ρ	-	Density of the roll
d	-	Initial diameter of wire roll
A	-	Cross-section area of web

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Winder system is one of system that currently uses in all industry. Commonly, this system applied in manufacturing industries such as rolling process and cable industries. Winder system consists of rewind, unwind and roller as a complete system. Until now, Programmable Logic Controller (PLC) is usually implement to run this winder system. By using PLC controller, this system will conduct according to sequencing of instruction in ladder diagram form. Although, from year to year more improvement are setting in this system to make it stable and more consistent when it running. This is because the winder system have many parameters to consider and need an action to improve it. The examples of parameter that need to consider are tension of wire and speed of motor. But now, rarely we can see the winder system have include the pendulum dancer as a main part in that system. Because of that, in this paper position of pendulum dancer is one of main parameter that needed to consider and analyze. Before considering the parameter, user should know all the process that producing in winder system.

In this paper, wire winding machine will be as a prototype. There are two process while producing in this system, which is unwinding process and rewinding process. Unwinding process is the first winder that will be drawn the wire from the bigger diameter to specific diameter that required in rewinding process, while rewinding process is a process that taking of wire in required value of diameter in its roller. The final process in this winder system is rewinding process.

Pendulum dancer is an instruments that situated in particular region of the handling line to manage tension control. One of the targets in winder system is to achieve a normal speed while keeping up the tension in the whole preparing line. The utilization of pendulum dancer can be partitioned into two classes, passive and active dancer [10].

Pendulum dancer are essentially utilized for tension disturbance that required a tension estimation that gave by a load cell. The position of pendulum dancer is moving by an actuator that demonstrations towards the pendulum dancer. Pendulum dancer principle part is to avoid the quick expansive tension varieties damping attributes.

In wire winding process, tension of wire will affect the quality of winding in end process. When machines run, the diameter of coiler in unwinding process will be decrease and its will be unwinding fast in order to maintain the speed. In the same time, in rewinding process the diameter of wire will become larger in its roller. The pendulum dancer is play the important role in this machine which is to correct the take-up winder speed in order to maintain in position too. The position of pendulum dancer will be affect according to variation of speed which is in high speed, middle speed and low speed.

In this paper, in order to maintain the position and speed of pendulum dancer in this wire winding machine the PID controller will be implement which is setting the PID controller in inverter D700. The gain scheduling method will be approach to tune the parameter in PID controller which is the value of integral, derivative and proportional. The simulation and experiment setup will be introduced in next chapter.

1.2 Objective

The targets of this project are:

I. To identify the mathematical model for position of the pendulum dancer in winder system.
II. To develop PID controller for winder tension system.
III. To analyze the performance of parameter controlled in winder system by using PID controller.

1.3 Motivation

Improvement in this winder system is still going on research to get the very stable and consistent to user. This is because, the winder system is one of unstable system among others system that commonly needed to analyze from time to time. Up to this point, a ton of papers that do the examination on winder system is consider the parameter of speed and tension in twisting procedure keeping in mind that end goal is to get the great performance of end process before item sent to client. Lots of industries today spend high cost to buy and maintain the winding system because it played an important role in marketing their products. To improve winder system in industries, in this paper PID controller approached to achieve the objective.

1.4 Problem Statement

The purpose for this winder system is to prevent web breaks, folding, or damage that may slow down or even can stop the process. Meanwhile, when the speed of the motor is too fast the cable might be broken. In wire industries process, the winder system is the last process that will be consider before item sent to client. Else, it is expected to ensure that there is no rejected things from client. In order to save the quality of product, PID controller will plays role to maintain the speed of the motor and position of pendulum dancer in processing line based on proportional term (K_P), integral term (K_I) and derivative term (K_D) .In order to implement the controller, first of all we need to ensure that the maximum and minimum reading of the position of pendulum dancer that detected by the sensor is suitable for the wire resistance and performance.

1.5 Scope and Limitation

The scope of work is clearly to establish mathematical model of pendulum dancer in winder system and to study about control performance of the system by using PLC program and MATLAB Simulink. Next step is to plan the experimental setup and perform the experiment to analyze the performance before and after implement the controller. The position sensor that uses to control the speed of the motor is the MIDORI Green Pot Precision Angle sensor. Last step is to collect data from Simulink MATLAB based on experimental and adjusted the parameter of PID according to performance.

In this paper, the Programmable Logic Controller (PLC) that used is from Mitsubishi FX34-16M. This PLC controller have a little bit difference language with PLC OMRON type. In setup process, pendulum dancer will be the plays important role that will be analyze. The pendulum dancer is work according to instruction in ladder diagram given. So that, the pendulum dancer should be setup the setting in initial condition first before run the system. In simulation part, the software that will be use is GX Developer for run the PLC program, micro box is used through MATLAB to observe the performance according due to parameter setup. Two AC motor is used to deliver the cable from one spool to another spool.

CHAPTER 2

LITERATURE REVIEW

In this Chapter 2 will be highlighted the important thing in previous thesis that related to the winder system which is in term of general overview about winder tension system, controller that used (PID), the parameter that control, tools that they used, technique of controller, and type of PLC used.

2.1 Winder Tension System

Winder system is one of system that currently uses in all industry. Commonly, this system applied in manufacturing industries such as rolling process and cable industries. Winder system consists of rewind, unwind and roller as a complete system. Even for right now, Programmable Logic Controller (PLC) is usually implement in this system. By using PLC controller, this system will conduct according to sequencing of work in ladder diagram form. Although, from year to year more improvement that setting in this system to make it stable and more consistent.

Winder system consists of unwinding roller, rewinding roller, and static roller for complete transportation. There are two process while producing in this wire winder system, unwinding process and rewinding process. Unwinding process is the first winder that will be drawn the wire from the bigger diameter to specific diameter that required in rewinding process, while rewinding process is a process that taking of wire in required value of diameter in its winder. The final process in this winder system is rewinding process.

Numerous customer items are prepared as web at some phase of their processing. The nature of the completed item is quickly influenced by the web tension in the machine heading of the web transport framework, winders, and handling segments [2].

A winder tension system becomes one of important winding machine in industries today. The loop winders can be ordered by speed levels and limit of system. From multi speeded machines to medium, large and additional expansive machines, these machines come in different sorts and classes, playing out a scope of capacity. The common applications for a winder tension system are to wind coils for inductors, transformer motor and chokes. Coil winder strain system configuration is managed by a loop's complexity, material tension restrictions, machine versatilities, administrator intercession, creation volume and impediment of cost.

In this paper is focus to develop of PID-PLC based control strategy for winder system. Pendulum dancer will become the main role in this research where, the position and speed of dancer need to consider along the experiment and analysis part. Keeping in mind the end goal to keep up the speed and position of pendulum dancer, PID controller will beat the issue in this system.

2.2 PID Controller (Proportional Integral Derivative)

The most generally utilized control methodology is PID control, which is straightforward, robust and reliable. Be that as it may, the real mechanical creation process is frequently nonlinear, time-varying frameworks, because of the troubles in PID parameter tuning, customize the PID control is hard to accomplish the wanted control impact [11].

A PID controller control loop feedback instrument controller generally utilized as a part of Industrial control framework. PID controller is generally utilized as a part of mechanical plants since it is straightforward and strong. Mechanical process is subjected to variety in parameters, which is when significant make the framework unstable. So the control engineer are on search for programmed tuning strategy [13].

Although numerous creative techniques have been presented in the previous 50 years to handle more complex control issues and to accomplish better performance, the dominant part of modern procedures are still controlled by method for basic PID controllers. This is by all PID controllers, despite of their basic structure, guarantee satisfactory performance for an extensive variety of modern plants and their utilization (the tuning of their parameters) is well known among industrial operators.

Consequently, PID controllers give, in industrial situations, a cost or advantage execution that is hard to beat with different sorts of controllers. However, in light of their basic structure, PID controllers are especially suited for pure first or second-arrange process, while industrial plants frequently exhibit qualities, for example, high request, time deferrals, and nonlinearities.

In modern process, PID is generally utilized as a part of input control since PID controller can be comprehended as a controller that can take the present, the past and the eventual fate of the mistake into thought [9]. The technique utilized as a part of PID is the control circle input which making out of three terms.

The proportional controller delivers a yield esteem that is corresponding to the controller input which is available mistake esteem. The corresponding reaction can be control and balanced by duplicating the mistake by a consistent relative pick up (K_P).

The stability of the system depends on the proportional gain. If the proportional gain is very high, the system will not stable. In the event that the relative pick up is low, the control activity might be too little when reacting to framework unsettling influences. The corresponding controller will have impact of the lessening the ascent time however won't take out the enduring state mistake. In other word, it will diminish the blunder however no dispense with it.

An integral controller is relative to both the size of the mistake and the span of the blunder. An integral in a PID controller is the total of the quick error over time and gives the gathered counterbalance that should have been adjusted beforehand. Thusly, an integral control will have the impact of eliminating of the steady-state error, yet it might worse the transient reaction [1].

The derivative of the procedure error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain (K_D) Derivation action will improves the settling time by predicting system behavior. The rate of change of the controller output will be control by the derivative term. A derivative control will have the impact of expanding the stability of the framework, enhancing the transient reaction and diminishing the overshoot [9].

PID controller is broadly utilized as a part of modern plants since it is straightforward and robust. Industrial process is subjected to variety in parameters. In this paper, in order to maintain the speed and position of pendulum dancer in this wire winding machine the PID controller will be implement to get the best performance for the system by product requirement.

2.3 Parameter Controlled

Tension control is most important parameter during the assembly process in order to maintain the quality of the rolling material. The wire required right tension tolerances to achieve the quality winder wire in end process. There will be slightly problem will occur during the process if the consistency of the tension cannot be achieved.

In physics, anxiety describes the pulling pressure transmitted axially via a string, cable, chain, or comparable one-dimensional continuous item, or by using each quit of a rod, truss member, or comparable 3-dimensional item; tension can also be described because the movement-response pair of forces performing at every stop of said elements.

Web tension and speed are two main variables in order to achieve the expected final product quality in process. One of the main objectives in web handling machinery is to reach an expected web speed while maintaining the web tension within a close tolerance band over the entire processing line.

In the bundling and printing industry, pressure control framework is a critical part, particularly for the web press. The better tension control can ensure for the great print quality and increment printing efficiency. The tension that cause by web press is influenced by many elements, for example, diameter of roller, distance across of the paper move, printing speed, web press paper tension system is a nonlinear complex time-varying framework. Establishment of an exact tension framework scientific model is introduce in the outline of tension controller and utilization of cutting edge control hypothesis. Then again, planning tension controller, enhancing calculation of pressure controller and considering different strain elements establish the framework for the keen control framework developed on the press [11].

In addition, detrimental variation tension can also cause by unacceptable speed variation. In experimental, a pressure control arrangement of moving web is truly touchy to outside aggravations amid running procedure, particularly while the thickness of the web is under 50 micrometers. A period changing payload or torque of the driving engines can bring about serious pressure variety. A moving web under inadequate strain can't track appropriately and might be wrinkled furthermore can bring about in web disfigurement or even a web break [16].

In this paper, parameter of speed and tension of wire will be consider during testing and analysis part until end of process. Speed will be in three modes which is low, medium and high mode. Every mode have their own specific value to maintain the system when running. Tension of wire also consider in order to prevent from wire broken or bad quality in end process. In order that, pendulum dancer will be control all the needed parameter according due to PID setting. Pendulum dancer will be moved due to specific speed of motor to prevent wire become loose.

2.4 Technique of Tuning Controller

The qualities of extensive time delay, non-linearity, and strong disturbance, the web tension control is the fundamental trouble of the rewinding process. The PID calculation can't accomplish great performance when the rewinding procedure is working under deceleration or acceleration. The new algorithm based on fuzzy control adaptive PID algorithm could solve this problem. This is on account of this calculation can be effectively acknowledged by programmable rationale controller (PLC) also. On that way, the PID parameters can be balanced specifically by utilizing fluffy rationale hypothesis. From that outcome demonstrates the new strategy can give the better element execution to the framework and higher strength and more grounded heartiness [8].

PID control is the most broadly utilized as a part of control procedure. This is on the grounds that this controller is straightforward, powerful and solid. In any case, in the genuine modern generation handle it is regularly nonlinear, time-fluctuating frameworks because of the challenges in tuning the PID parameter. Ordinary PID control is hard to accomplish the sought control impact. Fluffy versatile PID controller surmising utilizing the control rules for fluffy master framework and conforms PID control parameters web based by real circumstance of the controlled framework to make the framework a decent dynamic and static execution [11].

The model free of PID controller strategy with fluffy neuron pick up booking is proposed for turning forms. The without model PID controller is intended to keep the slicing power to be steady by changing the controller pick up on-line when a cutting device cuts at different cutting profundity or the axle works in various speeds so as to improve the control framework soundness and versatility to the plants with vulnerabilities and nonlinearities. In control framework, PID controller is utilized to control the turning procedure, the neuron U connected to tune the PID controller pick up, and a fluffy plan is set up to change the neuron pick up [7].

Gain scheduling is a technique where PID controller parameters (gains) are tuned during control process, using the fuzzy rule base system. It is not always counted as an adaptive control, but it enlarges the operation area of a PID controller to perform well also for a nonlinear plant with unpredictable parameter variations. In the proposed work, a fuzzy supervisor with two inputs-three outputs is used to schedule the controller parameters according to predefined parameter values with respect to changing operation conditions. The input variables are error and change in error and the outputs are K_P,K_I, and K_D.

In this paper, auto tuner PID technique is used to tune the PID controller by using Simulink and the value of PID was implement into this system to make the system stable and more efficient. For the final analysis, this tuning when the plant is not include PID controller and compare the result when plant implement the PID controller performance.

2.5 Programmable Logic Controller (PLC)

In 1968, Programmable logic controllers (PLCs) was Invented as a substitute for hardwired relay panels in National Electrical Manufacturing Association (NEMA). In that article says that, by implementing specific functions such as logic sequencing, timing, counting, and arithmetic the Programmable rationale controllers (PLCs) is a carefully working electronic mechanical assembly which utilizes a programmable memory for the interior stockpiling of guidelines to control, through computerized or simple information or yield modules for different sorts of procedures. To perform the functions of a programmable controller is considered to be within this scope the digital computer will be use.

Programmable logic controllers (PLCs) have been an integral part of industrial process control for decades and factory automation. PLC will control a wide exhibit of uses from straightforward lighting capacities to handling plants. These frameworks perform many capacities and give an assortment of simple and computerized information and yield interfaces, for example, flag handling, information change and different correspondence conventions. PLC's segments and capacities are determined to the controller, which is modified for a particular undertaking. The schematic diagram for programmable logic controller (PLC) is shown in Figure 2.1. The basic components of PLC are power supply, processor/CPU, input/output interface module, memory and programming devices.

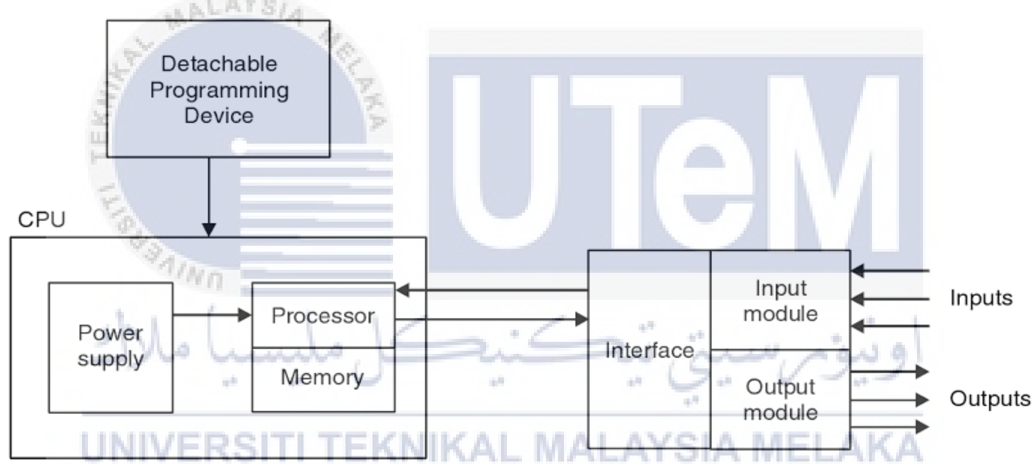


Figure 2.1: Block diagram of components of PLC

Ladder diagram is a main programming that used in PLC system. Ladder diagram is a diagram that contain instruction set to create the programmable controller program. The PLC goal is to control the output based on the input conditions. Rung in ladder diagram used to control system. Figure 2.2 will represent the example of simple ladder diagram in PLC controller.

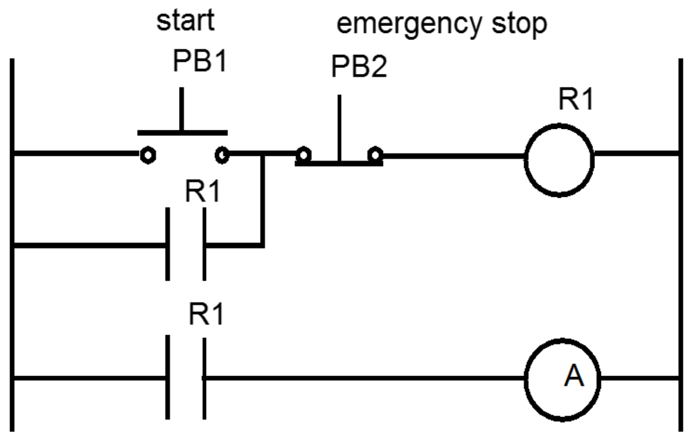


Figure 2.2: A ladder diagram

In wire winding system, Mitsubishi A series arrangement PLC will be utilized as an ace station of PLC in light of the fact that it has the normal for incredible capacity of data preparing and can give the fast reaction. To control the practices of the aggregate winding framework together with FX arrangement PLCs of unwinding and rewinding process. The grouping of these activities were altered heretofore into the control program by the client. To advise the PLC how to control a framework, the control program sets a progression of operations of the winding framework. In a PLC controlled assembling framework the PLC program is the premise of checking.

2.6 Micro-Box 2000/2000c

Micro-Box is developed by TeraSoft Inc. which is strong multi-work stage for quick control prototyping applications and a moderate. This micro box is to lead proficient designing arrangements supplier situated in Taipei and Taiwan. This micro box is works consistently with the Math Works group of items including Simulink, MATLAB, Simulink Real-Time, MATLAB Simulink Coder, which is empower designers to demonstrate physical frameworks and execute them in real-time.

Micro-Box is an elite modern PC and rough with no moving parts inside. The item bolsters all standard PC trademark including mouse, video, and console. For designers who have ongoing examination and control frameworks testing needs, Micro-Box offers a fantastic blend of execution, minimized size and I/O expandability. A choice of information and yield alternatives are accessible giving, bolster for TCP/IP, SCI, and PCI express based DI/O, AD/DA, and recurrence I/O modules that necessities. Miniaturized scale Box is incorporated with MATLAB Simulink and related control modules permitting the client to direct continuous demonstrating and fast prototyping, reenactment of control frameworks and equipment testing without the need of entangled investigate procedures and manual code era. This outcomes in noteworthy diminished improvement time and cost reserve funds.

In this paper, micro box is use to get the data to form the transfer function and get the output graph of performance from experimental setup. The setup for this Micro box will introduce in methodology part.

2.7 Inverter (Mitsubishi D700)

The FR-D700 arrangement is consistent to the EU Machinery Directive without the expansion of already required outer gadgets. The wiring got to be distinctly less demanding and more secure with spring clasp terminals. The outline life of the cooling fan has been reached out to 10 years. By using the ON/OFF control, the life of the fan can be further amplified. By the reception of a capacitor perseveres through 5000 hours at 105˚C encompassing air temperature the plan life of the capacitors has been stretched out to 10 years [16].

In this paper, Inverter D700 is using to give the speed value of motor to run whether in motor rewinding and unwinding. The value of speed is determine in three condition which is high speed, middle speed and low speed. The variation of speed setup is according due to pendulum dancer and tension of wire performance. Others than that, PID controller can be setup in this inverter. This inverter have its own parameter setting that can turn ON PID controller function as well as we want.

2.8 Converter (FX2N-2AD)

FX2N-2AD is a sort of simple info piece is utilized to change over the simple contribution of two focuses voltage and current contribution to a computerized estimation of 12 bits and to forward the qualities into the Programmable Controller. FX2N-2AD can be interface with the FX0N, FX2N, FX1N, and the FX2NC arrangement Programmable Controllers. The voltage or current contribution by the strategy for interfacing wires the simple info is chosen. Around then, by expect the setting to be two channels basic simple information which are voltage or current info. The simple to computerized change attributes can be balanced. The square involves 8 I/O focuses which can be designated from either data sources or yields. The information exchange with the PLC utilizes the guidelines [17].

In this paper, this converter function to convert the analog data to digital data that getting in performance analysis. Refer to pendulum dancer controlled, the position as given is in analog condition according to PLC ladder diagram setup. So that, has output from converted will doesn't have to convert manually.

2.9 PLC (Mitsubishi FX34-16M)

In wire winding system, Mitsubishi A series arrangement PLC will be utilized as an ace station of PLC in light of the fact that it has the normal for incredible capacity of data preparing and can give the fast reaction. To control the practices of the aggregate winding framework together with FX arrangement PLCs of unwinding and rewinding process. The grouping of these activities were altered heretofore into the control program by the client. To advise the PLC how to control a framework, the control program sets a progression of operations of the winding framework. In a PLC controlled assembling framework the PLC program is the premise of checking.

In this paper, this type of PLC have created the ladder diagram to give instruction to winder system and condition of speed and position of pendulum dancer. In ladder diagram, it consist of several type of instruction same with OMRON PLC type. This PLC work well for this system as instruction given to it.

CHAPTER 3

METHODOLOGY

In this Chapter 3, the methodology for this project will be explained thoroughly. There are three main parts that needed to be considered for completing this project. First step is to identify the transfer function that shown the pendulum dancer characteristic. The second step is to implement the PID controller through inverter setup in the winder system. The last part is to perform experimental and analyze the performance before and after include PID controller in this winder system. The PID work based on the sensor that detect the changes of the pendulum dancer in system. The PID used to control and adjust the speed of the motor. The PID give the signal or command to the PLC based system when the change of the tension is detected by the MIDORI sensor. The PLC will control the speed of the motor when change of the pendulum dancer is detected. When the dancer is move upward, the speed of motor will speed up. Meanwhile, when the dancer moves downward, the speed of the motor will become slow. The speed of the motor work in the range of speed that suitable for the EDM wire.

3.1 Mathematical Modelling

3.1.1 Unwinding Tension

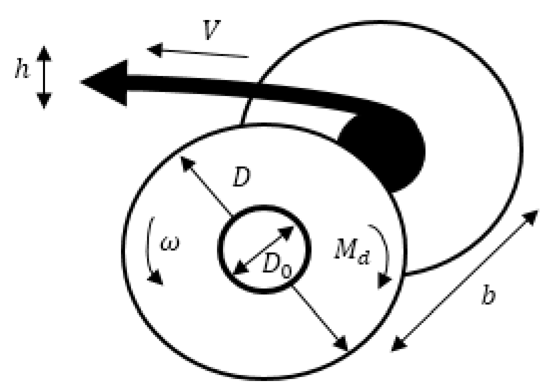


Figure 3.1: Unwinding tension part.

Where,

M_d	Braking torque acting on unwinding roller
ω	Angular velocity of the unwinding roll
V	Linear velocity of wire
D	Diameter of unwinding rolls
D_0	Roll's diameter
b	Roll width
h	Roll thickness (thickness of wire)

Dynamic torque equation of unwinding:

$$\frac{\mathrm{d(J\omega)}}{\mathrm{dt}} = \frac{\mathrm{TD}}{2} - \mathrm{M_d} - \mathrm{B_f(t)\omega} \tag{3.1}$$

Tension is derived as below:

$$T = 2\frac{M_d}{D} + 4\frac{B_f}{D^2}V + \left[-\frac{3}{4}\rho bh + \frac{8hJ_0}{D^4\pi} - \frac{\rho bh}{4}\left(\frac{D_0}{D}\right)^4\right]V^2 + [\frac{4J_0}{D^2} + \frac{\rho bD^2\pi}{8} - \frac{\rho bD_0{}^4\pi}{8D^2}]\frac{dv}{dt} \tag{3.2}$$

Where,

T	Roll tension
M	Roll quality
J	Inertia of unwinding roll
J_k	Inertia of wire on the unwinding roll
J_o	Inertia of core shaft of unwinding roll
B_f	Damping coefficient
ρ	Density of the roll
d	Initial diameter of wire roll

For the details derivation, refer to paper [16]. By (3.2), it is observed that the unwinding tension is effect by a number of factors: unwinding speed, volume diameter, the inertia of web roller, paper roller diameter, paper density, paper thickness and the friction coefficient. Tension is a polynomial of the line speed and the roll diameter, showing that tension system is a nonlinear, time-varying control object.

3.1.2 Position of Pendulum Dancer System

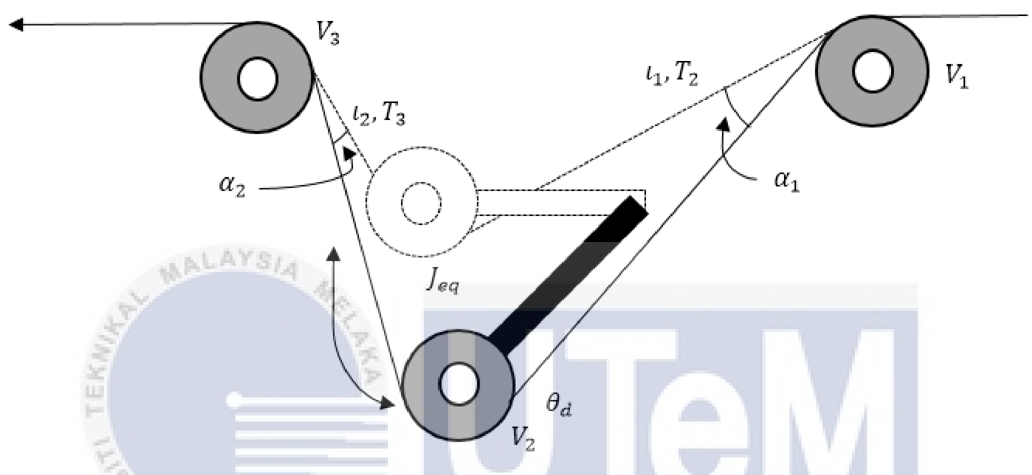


Figure 3.2: Position of pendulum dancer.

a) Tension model of dancer system

By law of conservation of mass of control volume which means that the change of the mass of web in span is equal to difference between the amount of mass of web span coming from previous span and the mass of web span leaving for the next span.

$$\frac{d}{dt}\int_{\iota=0}^{\iota=u(t)} \rho(\iota,t)A(\iota,t)dx = \rho_u A_u V_1(t) - \rho_u A_u V_2(t) \tag{3.3}$$

Where,

ρ	Density of web material
A	Cross-section area of web
$V_1(t)$=$V_2(t)$	Velocity of roller 1 & 2
$\iota = u(t), \iota = 0$	Web position on the roller 1 & 2

Consider an infinite element of the web in the longitudinal direction. The length, width and height of the element are given:

$$dx = (1 + \epsilon_x) dx_u \tag{3.3}$$

$$w = (1 + \epsilon_w)\, w_u \tag{3.4}$$

$$h = (1 + \epsilon_h)\, h_u \tag{3.5}$$

Where,

$\in$ Unscratched state

Mass of the infinite element of web:

$$d_m = \rho(x,t)A(x,t)dx = \rho_u(x,t)A_u(x,t)dx_u \tag{3.6}$$

Substitute (3.3) into (3.6),

$$\rho(x,t)A(x,t)dx = \rho_u(x,t)A_u(x,t)dx_u$$

$$\frac{dx_u}{dx} = \frac{\rho(x,t)A(x,t)}{\rho_u(x,t)A_u(x,t)} = \frac{1}{(1 + \epsilon_x)(x,t)} \tag{3.7}$$

So that, mass conservation equation,

$$dx_u = \frac{1}{(1 + \epsilon_x)(x,t)} dx \tag{3.8}$$

Substitute (3.8) into (3.6),

$$d_m = \frac{d}{dt}\int_{x_i}^{x_{i+1}} \frac{\rho_u(x,t)A_u(x,t)}{(1 + \epsilon_x)(x,t)} dx$$
$$= \frac{\rho_{ui}(x_i,t)A_{ui}(x_i,t)V_i(t)}{(1 + \epsilon_x)(x,t)} - \frac{\rho_{ui+1}(x_{i+1},t)A_{ui+1}(x_{i+1},t)V_{i+1}(t)}{(1 + \epsilon_{i+1})(x_{i+1},t)} \tag{3.9}$$

Assume that ρ and A are constant. So that,

$$\frac{d}{dt}\int_{x_i}^{x_{i+1}} \frac{1}{(1+\in_x)(x,t)}dx = \frac{V_i(t)}{(1+\in_i)(x_i,t)} - \frac{V_{i+1}(t)}{(1+\in_{i+1})(x_{i+1},t)} \tag{3.10}$$

If assume $i = 1$,

$$\frac{d}{dt}\int_{x_1}^{x_2} \frac{1}{(1+\in_1)(x,t)}dx = \frac{V_1(t)}{(1+\in_1)(x_1,t)} - \frac{V_2(t)}{(1+\in_2)(x_2,t)} \tag{3.11}$$

b) Tangential velocity of a dancer roll

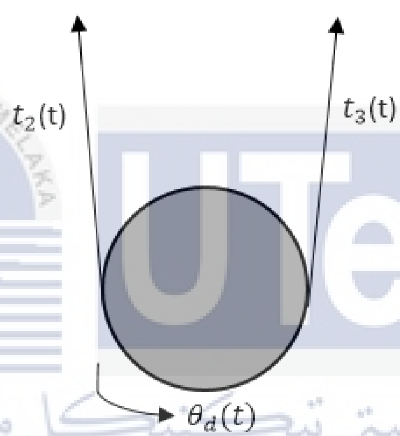


Figure 3.3: Torque of dancer.

Torque equation,

$$J_d\ddot{\theta}_d(t) = \{t_3(t) - t_2(t)\}r_d - b_d\dot{\theta}_d(t) \tag{3.12}$$

Tangential equation,

$$\dot{\theta}_d(t) = \frac{V_d(t)}{r_d} \tag{3.13}$$

Velocity equation,

$$V_d(t) = V_{d0} + V_d(t) \tag{3.14}$$

Substitute (3.13) into (3.12),

Torque must be in steady-state (equal to zero):

$$0 = (t_{30} - t_{20})\, r_d - b_d \frac{V_d(t)}{r_d} = (t_{30} - t_{20})\, r_d{}^2 - b_d V_d(t)$$

$$0 = (t_{30} - t_{20})\, r_d{}^2 - b_d V_{20} \tag{3.15}$$

Substitute equation (3.13), (3.14) and (3.15) into (3.12),

$$J_d \dot{V}_d(t) = (T_3 - T_2)\, r_d{}^2 - b_d V_d(t) \tag{3.16}$$

Tangential velocity is determined by the moment of inertia of the roll, roller radius and tension difference.

c) Tangential velocity of a dancer arm

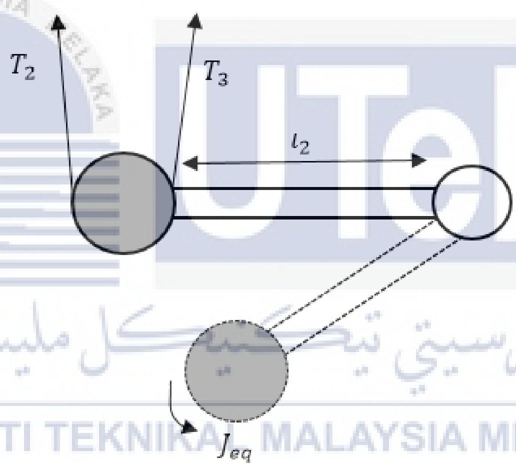


Figure 3.4: Force on dancer arm.

Torque equation will consider the up and down of the dancer depends on the tension of wire:

$$J_{eq} \ddot{\theta}_d(t) = -\iota_2\big(t_3(t) - t_2(t)\big) - b\dot{\theta}_d(t) \tag{3.17}$$

In steady-state condition:

$$0 = -\iota_2\big(t_3(t) - t_2(t)\big) \tag{3.18}$$

3.2 Modelling of Winder Tension System

There are two process while producing in this wire winder system, unwinding process and rewinding process. Un-winder process is the first winder that will be drawn the wire from the bigger diameter to specific diameter that required in re-winder process, while re-winder process is a process that taking of wire in required value of diameter in its winder. The final process in this winder system is re-winder process. Figure 3.5 shown the physical model of wire winding system for both process.

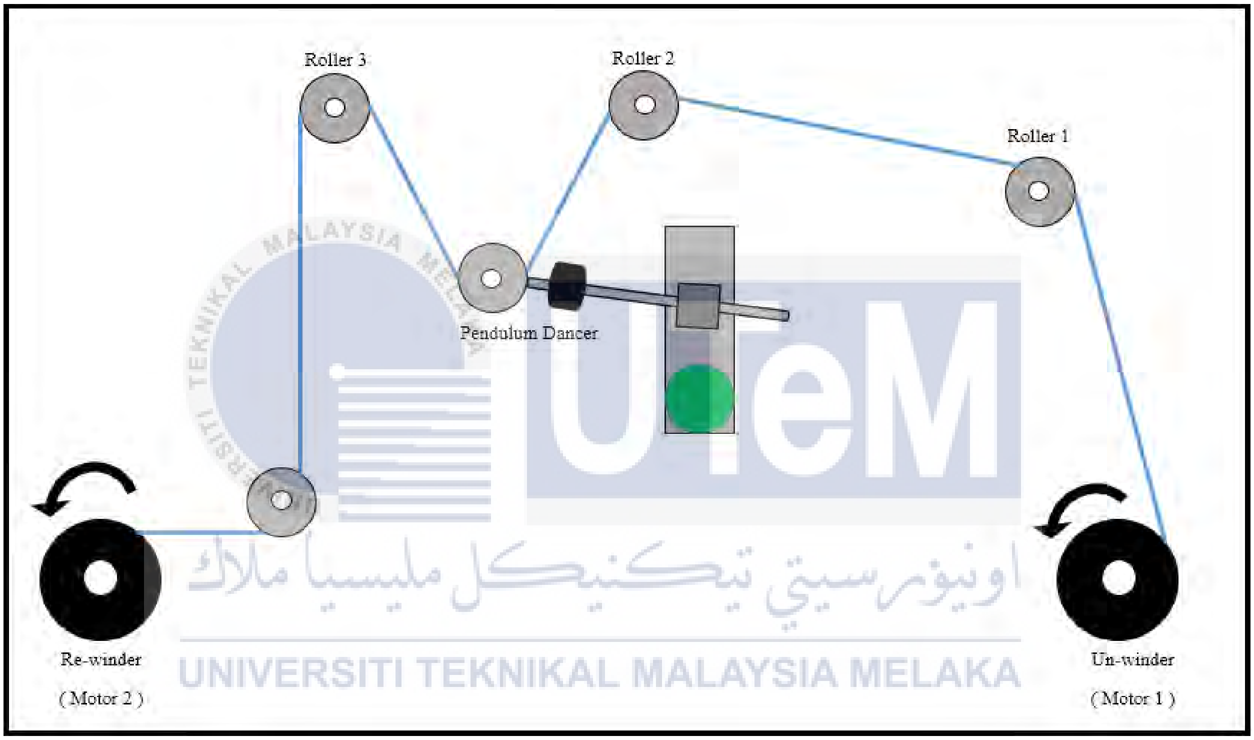


Figure 3.5: Physical model of wire winding system.

Pendulum dancer is an instruments that situated in particular region of the handling line to manage tension control. One of the principle targets in winder system is to achieve a normal speed while keeping up the tension in the whole preparing line. The utilization of pendulum dancer can be partitioned into two classes, detached and dynamic dancer [10].

Pendulum dancer are essentially utilized for tension aggravation that required a pressure estimation that gave by a heap cell. The position of pendulum dancer is moving by an actuator that demonstrations towards the pendulum dancer. Pendulum dancer principle part is to evade the quick expansive pressure varieties damping attributes. Figure 3.6 shown the pendulum dancer mechanism in this system.

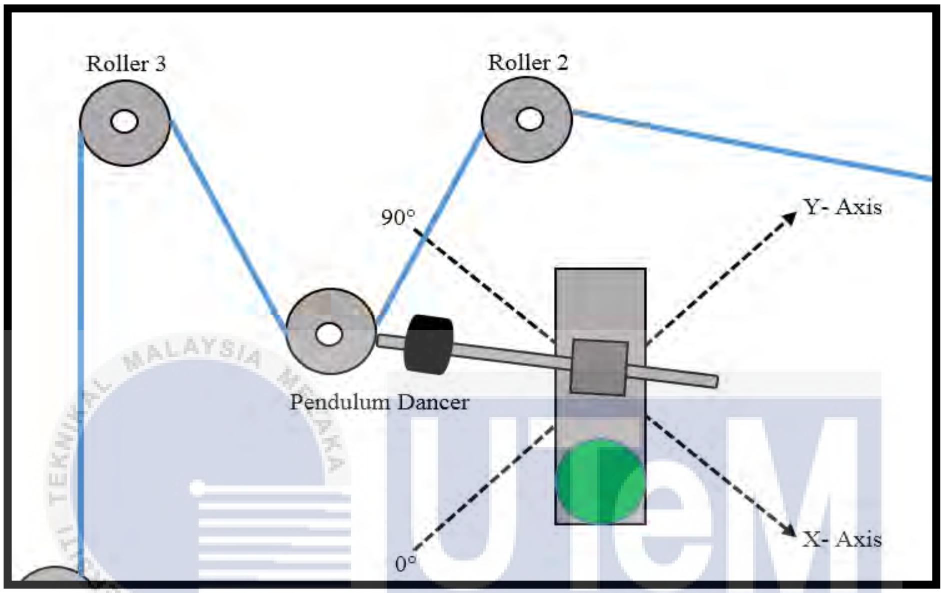


Figure 3.6: Pendulum dancer mechanism.

3.3 System Operation

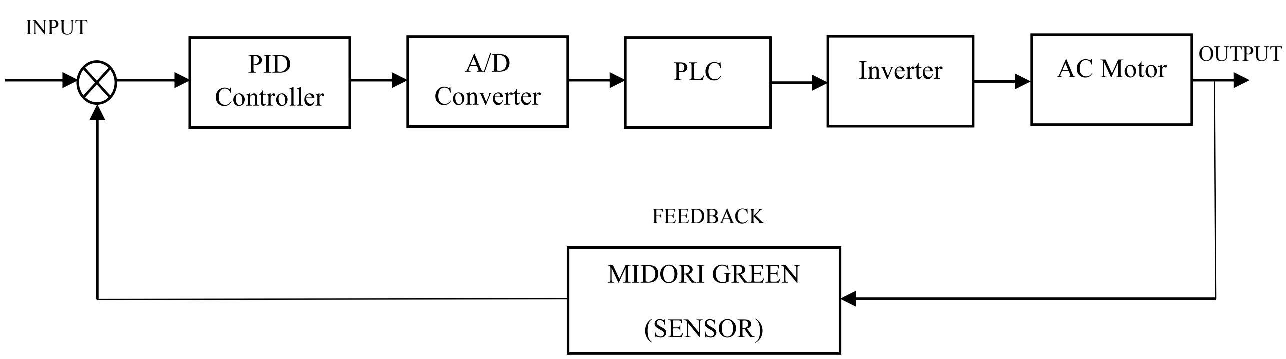


Figure 3.7: The operation of winder system.

This winding system will start when the push button is pressed. The wire from un-winder process will draw to re-winder process part. The AC motor will start to run with the initial set speed for the wire. The speed of motor will changing according to position of pendulum dancer when machine is running. The position of pendulum dancer will detected by MIDORI GREEN sensor and give the feedback to PID controller. PID controller will initialize the target value and measured value. It will generate a feedback that required the PLC to performed intended operations and send the feedback to the PLC based system. Analog digital converter will convert the digital signal received from PID controller to the analog signal and send it to the PLC based system. PLC will control the speed of the motor after received the signal form the A/D converter. The inverter used to help the PLC to speed-up and speed-down the speed of the motor based on the signal received from the sensor because the PLC cannot directly changing the speed. The motor will continuously running according to tension of wire and speed of motor in winder system.

3.4 PID Controller Tuning

In this project, PID controller will be implement in PLC programming setup to improve the system. In PID controller, there have three parameter that need to consider and setup. The three parameter are proportional gain, integral gain and derivative gain. All these parameter will be tuning based on the performance of system. The PID required to be tuning to find the stability and good transient performance.

The transfer function of PID controller form shown in below:

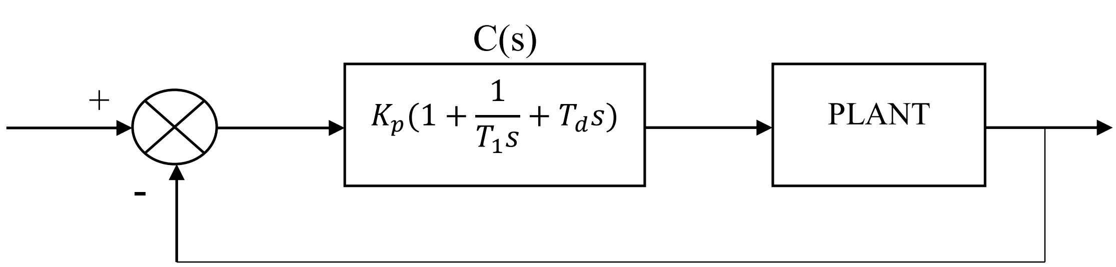


Figure 3.8: Block diagram of PID controller.

$$C(s) = K_p + \frac{K_i}{s} + K_d$$
$$= K_p(1 + \frac{1}{T_1 s} + T_d s) \quad (3.25)$$

where

$K_p = proportional\ gain$

$K_i = integral\ gain$

$K_d = derivative\ gain$

$T_1 = reset\ time = \frac{K_p}{K_d}$

$T_d = dead\ time$

The proportional term, K_P will use to diminish the ascent time. The proportional term, K_P is being tuning to establish the stability of the system and improving the transient response. The integral term, K_i is being tuning to set up the soundness of the framework and enhancing the transient reaction. However, the integral term, K_i will introduces a pole at $s = 0$ in the forward loop process. The derivative term, K_d is being tuning to reduce the overshoot, settling time and enhance the shut circle reaction. The impact of subordinate term can be accepted as the bolster data on the rate of progress of the deliberate variable into the controller activity.

In this paper, auto tuner PID technique is used to tune the PID controller by using Simulink and the value of PID was implement into this system to make the system stable and more efficient. For the final analysis, this tuning when the plant is not include PID controller and compare the result when plant implement the PID controller performance.

3.4.1 PID Controller Setup

In this project, PID controller has been setup manually in Inverter (Mitsubishi D700). Step to setup this PID controller has been learn due to its manual. In this inverter, each of the parameter has their own function. Following diagram shows the connection how to setup PID controller:

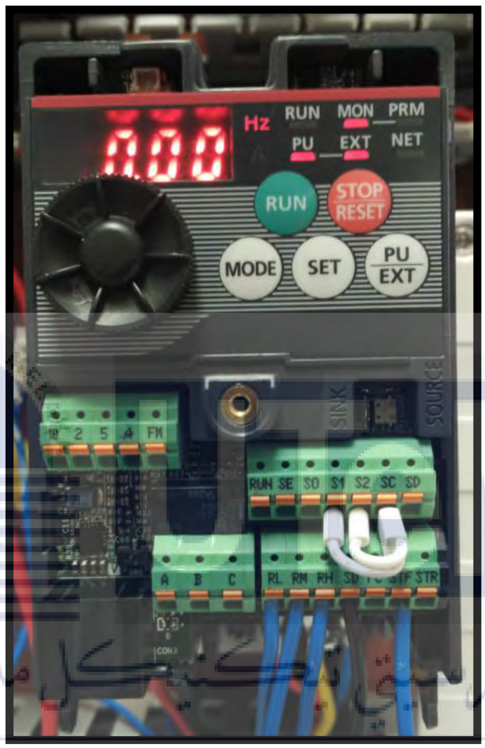


Figure 3.9: Interface of Inverter Mitsubishi D700.

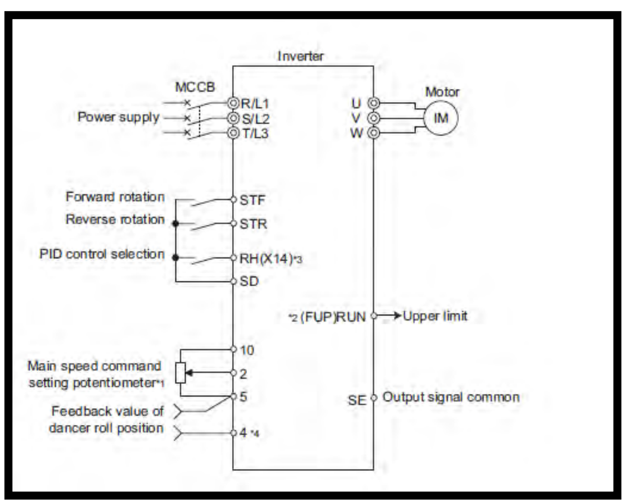


Figure 3.10: Connection of PID controller in Inverter.

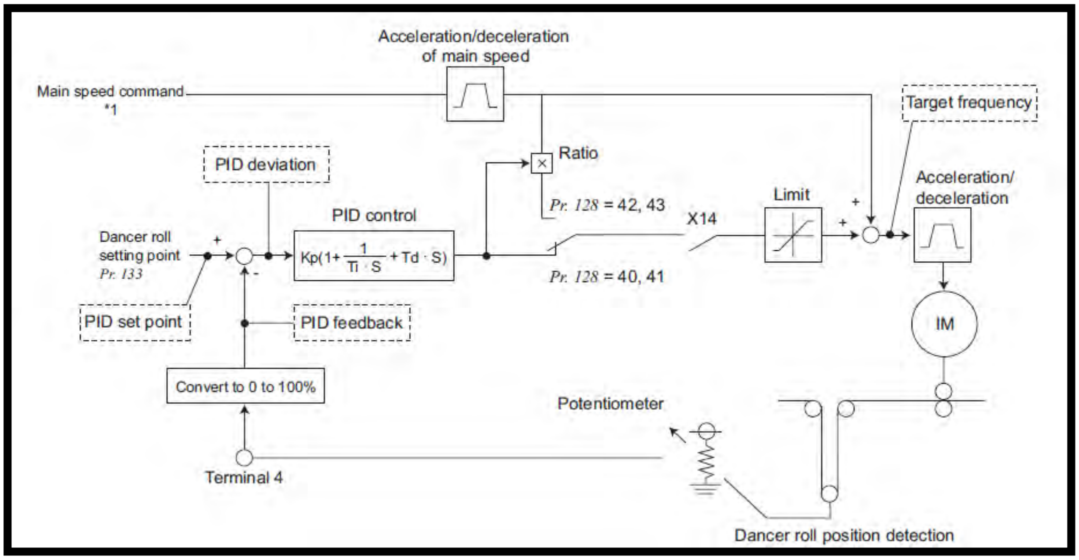


Figure 3.11: Dancer control block diagram.

Several parameter that have been set to perform PID controller in this winder system:

- Pr. 133: Set point of PID.
- Pr. 79: Set range to 3; Combined external and PU operation mode.
- Pr. 128 – Pr.134: PID operation.
- Pr. 575 and Pr. 576: PID operation (output interruption detection time and level).
- Pr. 182: Set to 14 for using terminal RH.

3.5 Matlab Simulink

MATLAB Simulink was used to create a block diagram which will represent the encoder and pendulum dancer from winder system. It uses a graphical user interface (GUI) to interact with the blocks that represent subsystems. It can also can position the blocks, resize the blocks, label the blocks, specify block parameter and interconnect blocks to form complete systems from which simulations can be run.

3.5.1 Creating Simulink Diagram

To create a Simulink diagram, first *'Simulink model'* icon at the top of the window was clicked and a new empty Simulink model will appeared to create new diagram of the block diagram. The, the *'Simulink Library Browser'* icon was clicked and all list of block diagram was appeared.

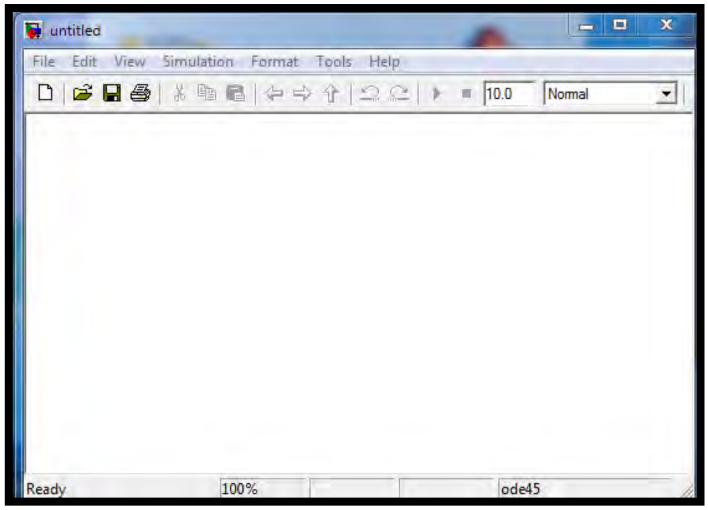


Figure 3.12: The new empty Simulink model.

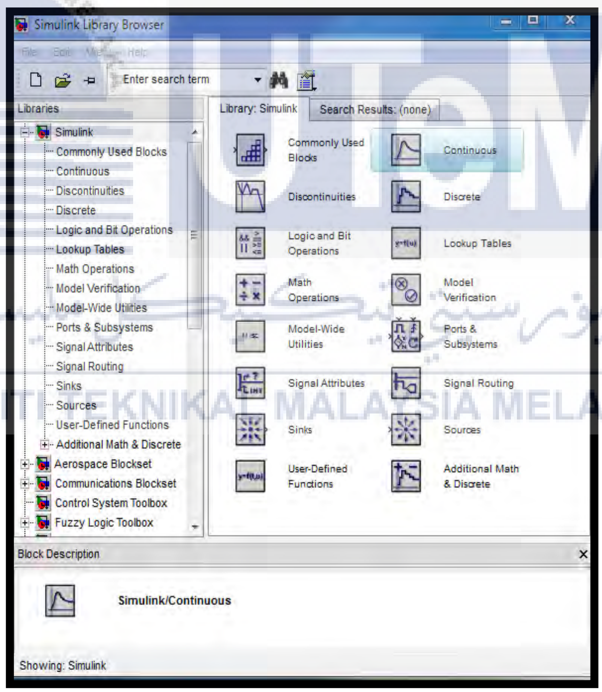


Figure 3.13: Simulink Library Browser.

After that, the appropriate blocks from Simulink Library Browser was chosen by click and drag the block to the new empty Simulink model. The connection between blocks is done by just click at the end of a blocks and drags the arrow to another block as shown in Figure 3.14.

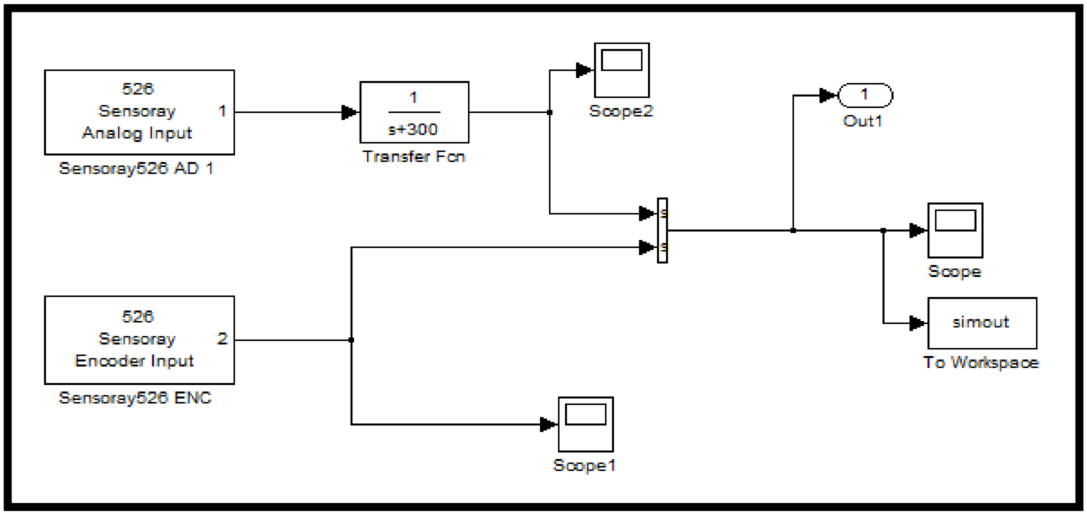


Figure 3.14: Simulink block diagram model.

3.6 Programming PLC by using GX-Developer

GX-Developer was used to create a ladder diagram and program the PLC. The ladder logic program is written offline and downloaded to PLC via USB cable. The program can be monitored and debugged while the PLC is still in communication with PC.

3.6.1.1 Creating ladder diagram

To create a new ladder diagram, first new icon at the top of the window was clicked and a new of configuration change PLC will appeared. The, the PLC series and PLC type was selected based on the type of PLC used as shown in Figure 3.15.

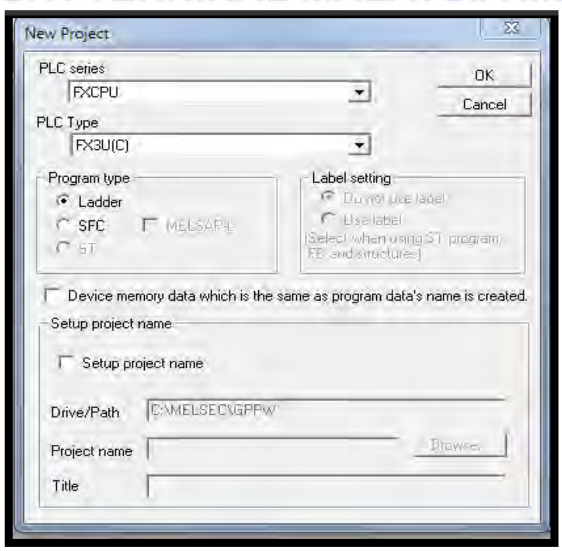


Figure 3.15: PLC change configuration.

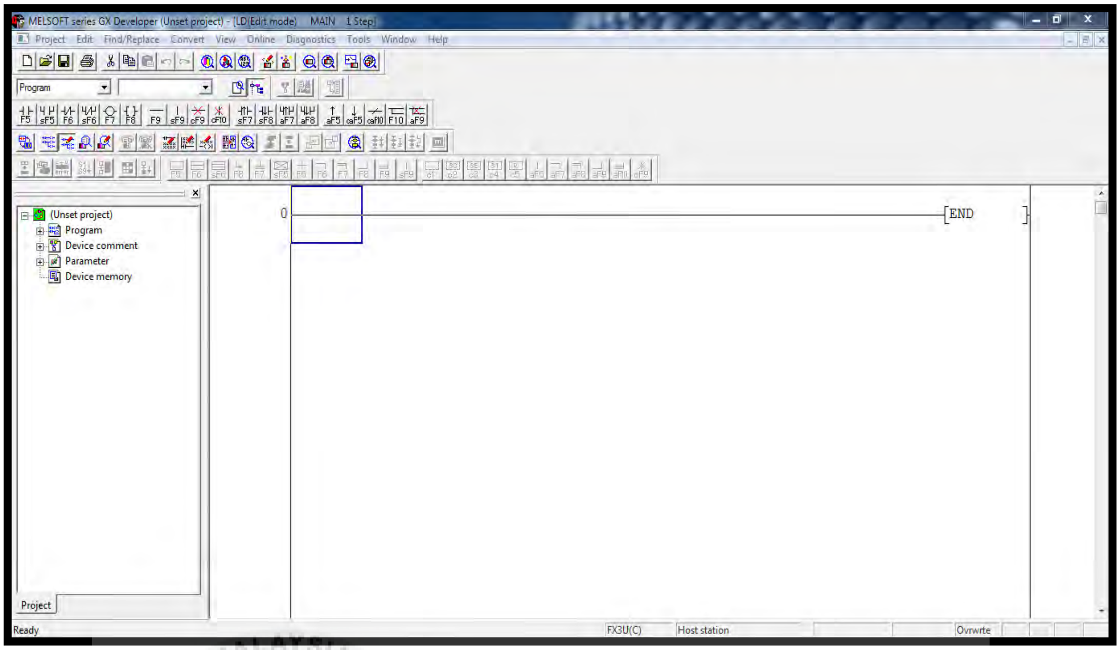


Figure 3.16: The new empty box on creating ladder diagram.

After the new empty box appeared, the appropriate function block was chosen by click at the toolbox that shown in Figure 3.17. The entire of ladder diagram was created sequential to make a full program.

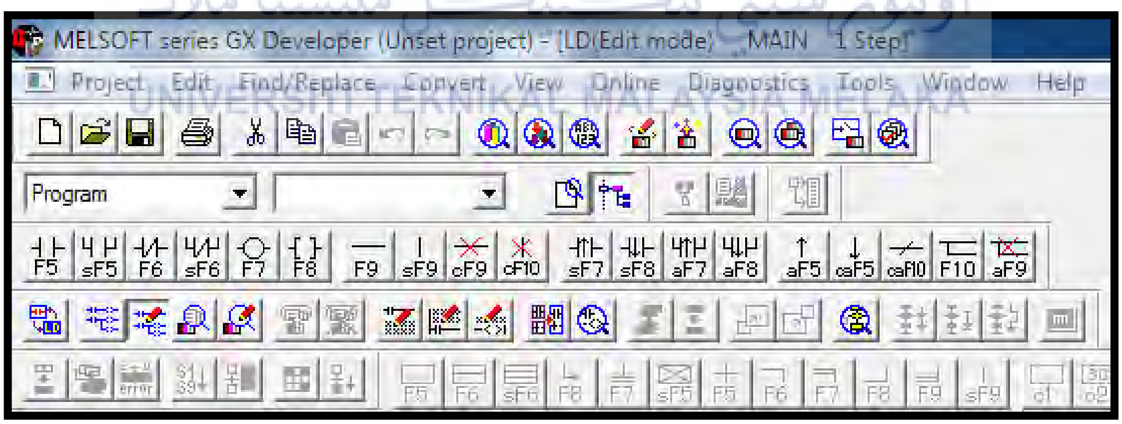


Figure 3.17: Toolbox that used to make a ladder diagram.

The name of each block was set by double-clicking at the particular block and the *'Enter symbol'* block will appear as shown in Figure 3.18.

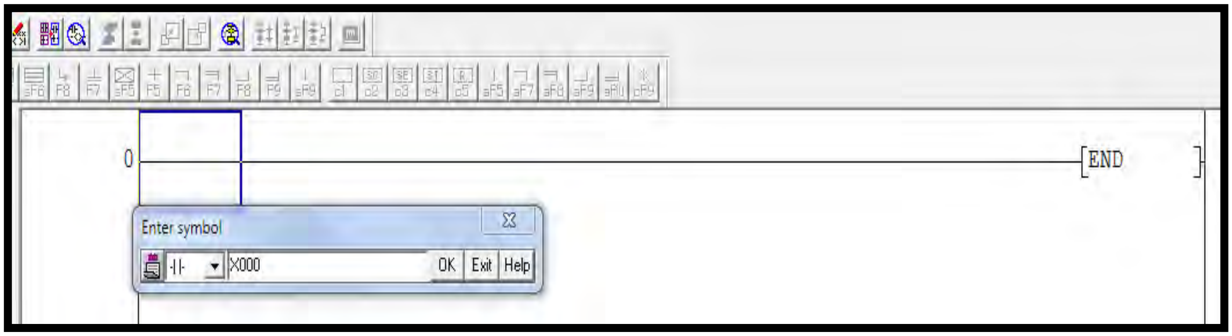


Figure 3.18: The *'Enter symbol'* block appear.

Figure 3.19: The block that has been set.

3.7 Experimental Setup (Hardware)

3.7.1 Winding Machine

In this winding machine consists of hardware and software part. In hardware and software part, there are several component that will be used in this project.

a) FX3u-16M Mitsubishi PLC

Figure 3.20: FX3u-16M Mitsubishi PLC

The Mitsubishi PLC will become the based system for the controller in the winder tension system. Figure 3.20 show the Mitsubishi PLC that will be used in this project [16].

b) MIDORI Green Precision Angle Sensor

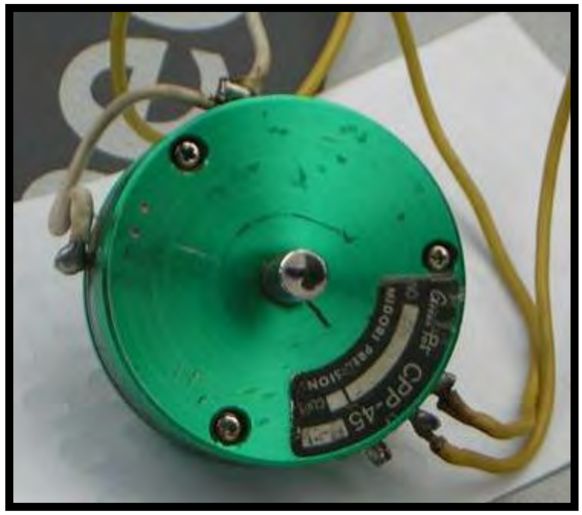


Figure 3.21: MIDORI Green Precision Angle Sensor.

The function is to detect the movement of dancer pendulum during the winding operation. Figure 3.21 show the MIDORI green precision angle sensor.

c) AC Motor

Figure 3.22: AC motor

AC motor used to control the speed of the motor compared to dc motor. In this project, two ac motor will be used. One for the un-winder and the other one for the re-winder. Figure 3.22 show the 240v AC motor that will be used in this project.

d) FX2N-2AD Analog Adapter

Figure 3.23: FX2N-2AD analog adapter

It will used when simple signs are caught from the Midori green sensor and are changed over to a computerized design so that PLC framework control can be executed. Figure 3.23 show the analog adapter that will used in this project [17].

e) Mitsubishi Inverter D700

Figure 3.24: Mitsubishi Inverter D-700

The function of the inverter to control the speed of the ac motor based on PLC command. Figure 3.24 show the Mitsubishi inverter that will be used in this project.

f) GX DEVOLEPER-FX

Figure 3.25: GX Developer-FX

This software is specifically used for Mitsubishi PLC system. It will be used to design and test the ladder diagram for the winder tension system. Figure 3.25 show the GX developer-FX software.

g) MATLAB

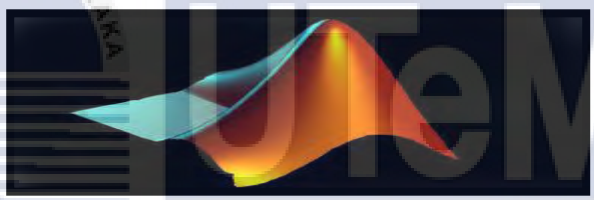


Figure 3.26: MATLAB

Grid lab is a multi-worldview numerical processing environment and forward era programming dialect. It allow plotting of function, matrix manipulation and data, implementation of algorithm. MATLAB will be used to stimulate the PID controller. Figure 3.26 show a MATLAB software.

h) MicroBox (xPC-Target)

Figure 3.27: MicroBox (xPC Target)

Micro-Box is an elite modern PC and rough with no moving parts inside. The item bolsters all standard PC trademark including mouse, video, and console. For designers who have ongoing examination and control frameworks testing needs, Micro-Box offers a fantastic blend of execution, minimized size and I/O expandability. A choice of information and yield alternatives are accessible giving, bolster for TCP/IP, SCI, and PCI express based DI/O, AD/DA, and recurrence I/O modules that necessities. Miniaturized scale Box is incorporated with MATLAB Simulink and related control modules permitting the client to direct continuous demonstrating and fast prototyping, reenactment of control frameworks and equipment testing without the need of entangled investigate procedures and manual code era. This outcomes in noteworthy diminished improvement time and cost reserve funds.

xPC Target is a capable and easy to use device for quickly actualizing constant control frameworks on a PC. The product works through MATLAB Simulink, permitting a control framework to be outlined in piece graph shape in Simulink and after that acknowledged in the physical world with no requirement for any low-level programming or circuit gathering. The piece chart is essentially incorporated to an executable and after that stacked onto a committed the Micro-Box for continuous execution. Figure 3.28 demonstrate the three noteworthy parts to any xPC Target control framework: The host PC, the Micro-Box, and the plant.

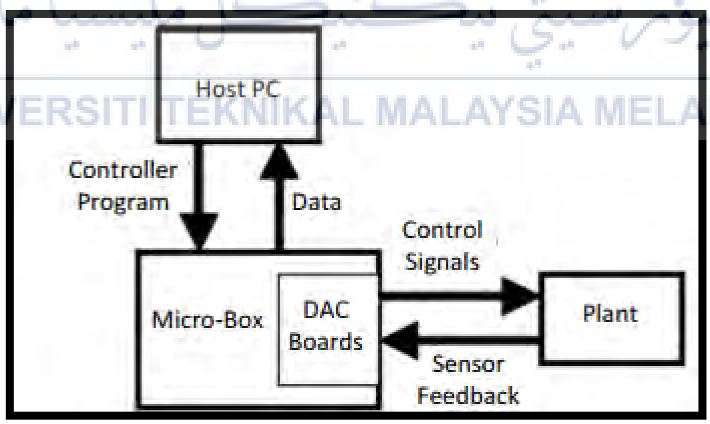
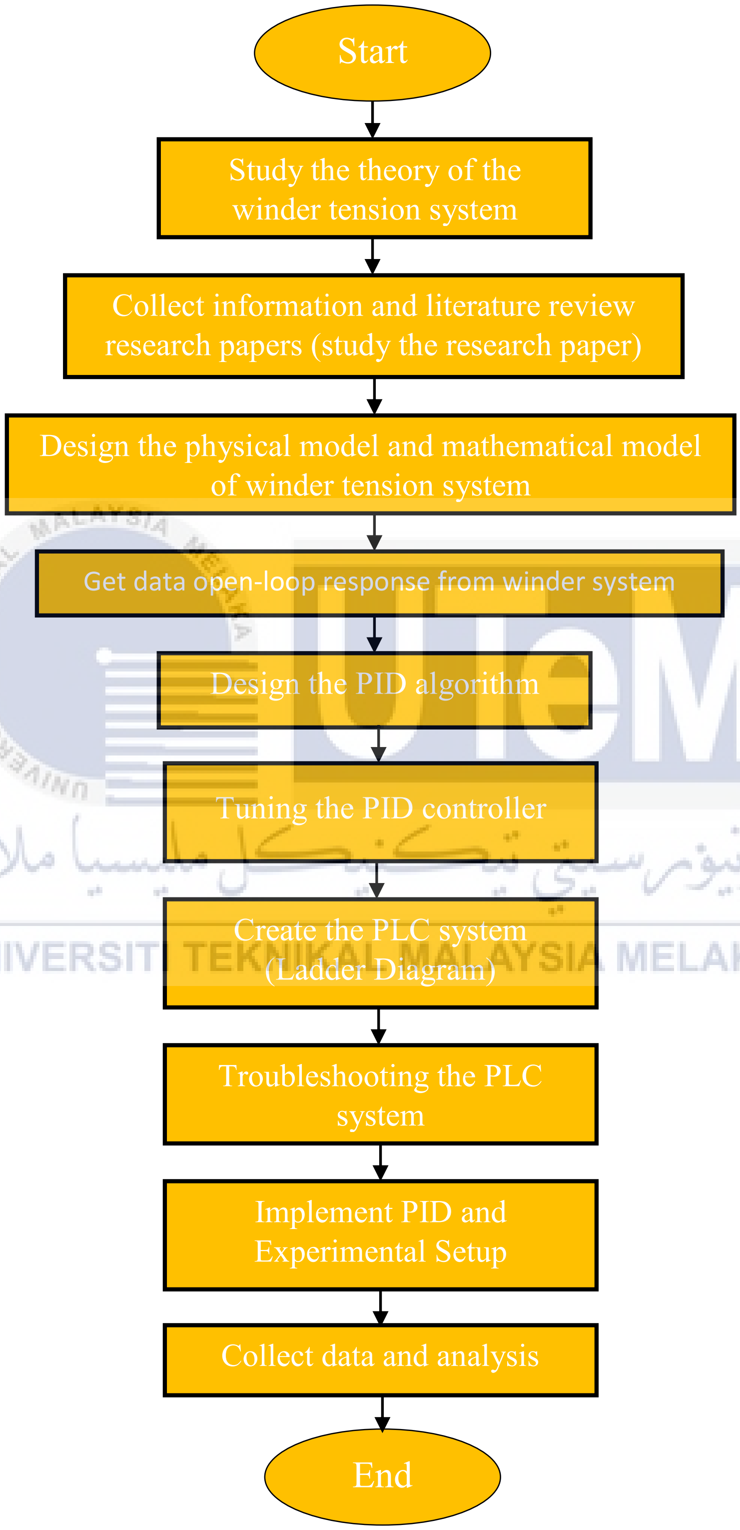


Figure 3.28: Component of xPC Target control system.

Beginning with create the Simulink block diagram model of xPC Target as in Figure 3.14. Then, connect the LAN cable from microbox to computer to link the system through it. Setup the Matlab in xPC Target mode by compiler setup. In this case, winding system need to run first to get the data of encoder and pendulum dancer movement. After that, run the Simulink block diagram by set the time in 30s, 60s and 120s for get different graph response. xPC-target box will send and got flag to loosen up and rewind framework. After the continuous control process is done, we have to transfer information from xPC target confine to PC. We can plot the chart in view of the information taken from the xPC-target box.

3.8 Project Implementation

3.8.1 Flowchart



3.8.2 Gantt Chart

Figure show the Gantt chart for Final Year Project.

Description / Month	SEPT	OCT	NOV	DIS	JAN	FEB	MAC	APR	MAY	JUNE
Literature Review										
Study about system by previous work										
Modelling of the system										
Simulation of system										
Variation of parameter										
Result and Discussion										
Thesis write up and submission										
Preparation for seminar II										

CHAPTER 4

RESULTS AND DISCUSSIONS

In this chapter, all results involves hardware and software part for support the operation. Mostly, the focus is given out the transfer function, PID controller design and PLC by using GX-Developer.

4.1 Getting Transfer Function by using System IDENT in Matlab

Here is the block diagram that use for getting the graph position of pendulum dancer. This clock diagram build in Simulink and run when the winding machine in run mode. In this case, time is set for 160 seconds and the below graphs show the result of pendulum dancer position in specific time.

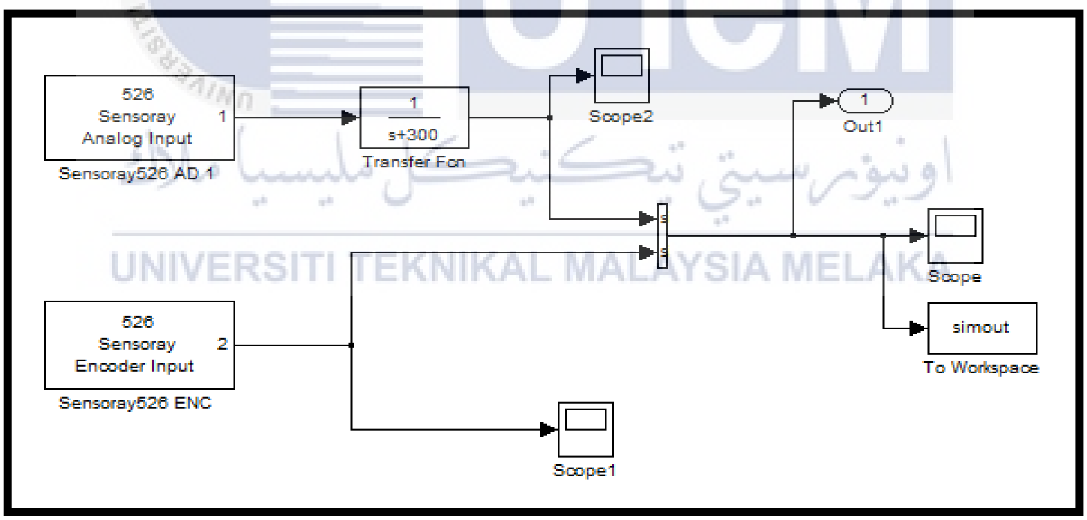


Figure 4.1: Block diagram for Real Time (Experimental).

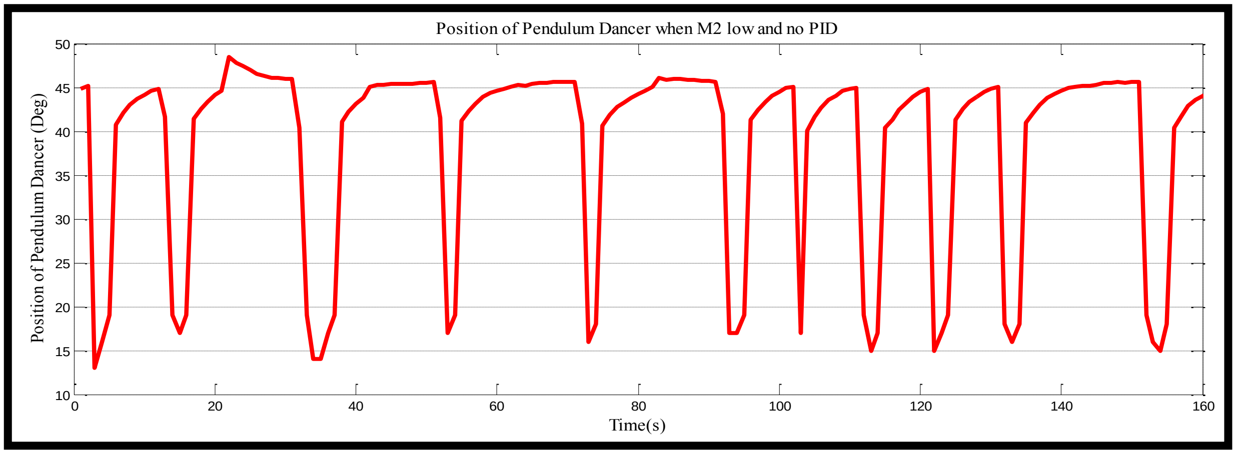


Figure 4.2: Graph of Pendulum Dancer (Position)

After the graph show up, to get the transfer function, system identification will work for it. In system identification, the estimation needed to get the best fits of transfer function according due to number of poles and zeros. Figure below shown that the step to get the transfer function by using *'system Ident'*.

Firstly, *'import data'* icon was selected in Matlab and data window will appear. Setup the name of *variable* and import the selection in workspace. Figure 4.3 shown that the window that appear on screen.

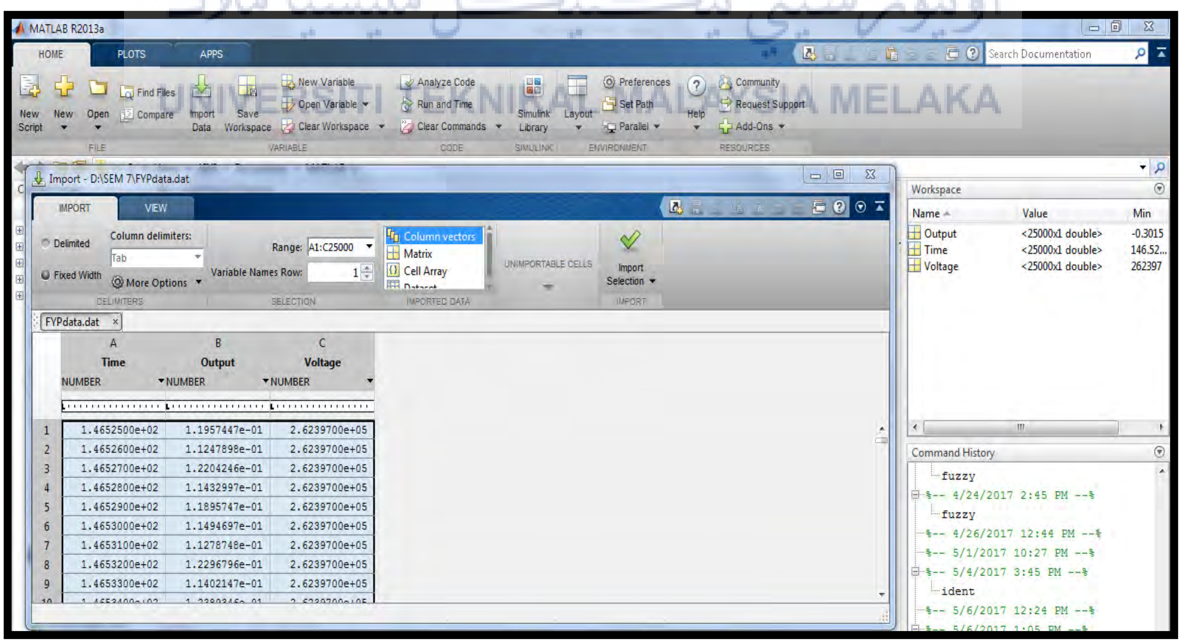


Figure 4.3: Import data into workspace.

Secondly, inserted the 'Ident' command in command window as shown in Figure 4.4.

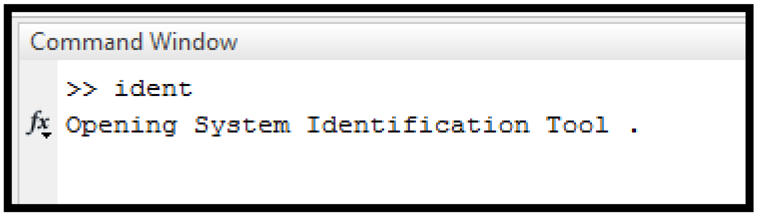


Figure 4.4: Command window.

After that, 'System Identification' window will appear select import data and inserted the workspace variable as shown in Figure 4.5.

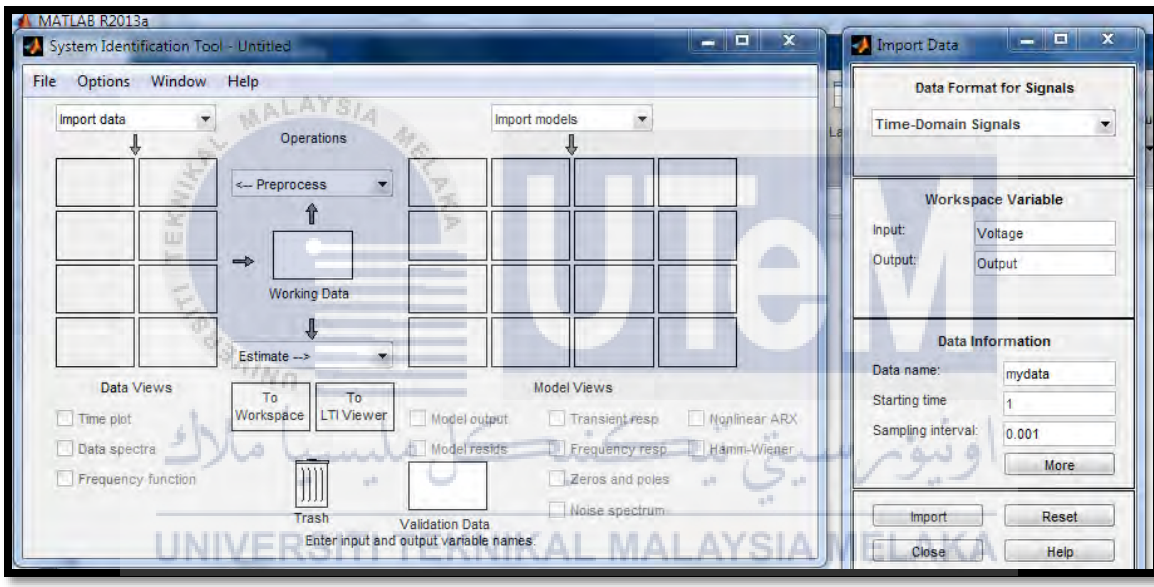


Figure 4.5: System Identification Tool.

Next, estimate the transfer function model by adding number of zeros and poles. For this system, the maximum number of poles is 2. Figure 4.6 shown the window of transfer function.

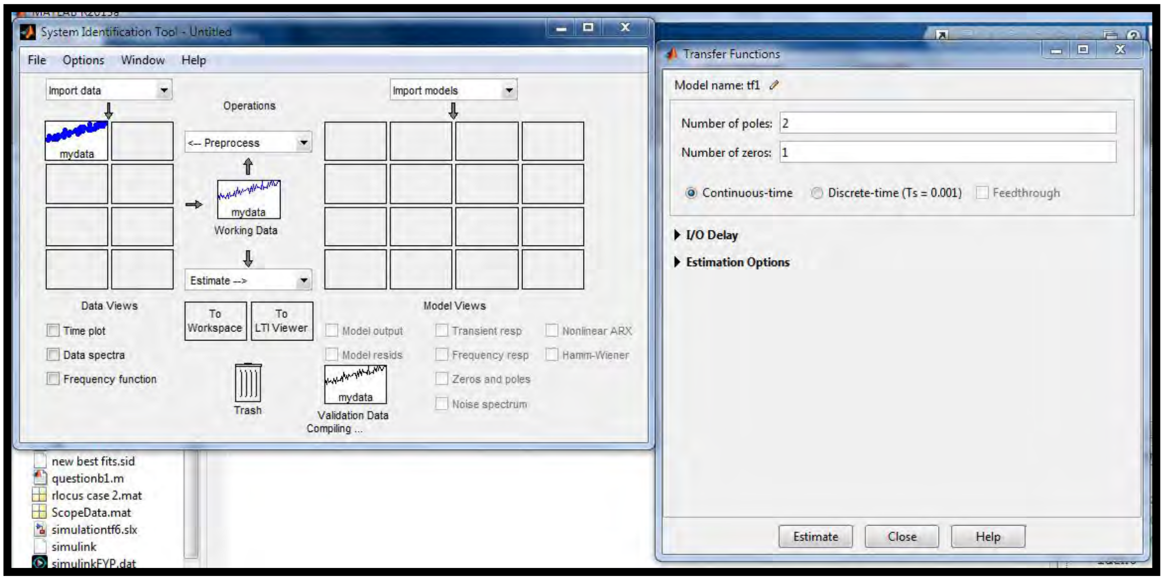


Figure 4.6: Transfer function estimation.

Finally, after done estimation the number of zeros and poles, model will appear as shown in Figure 4.7.

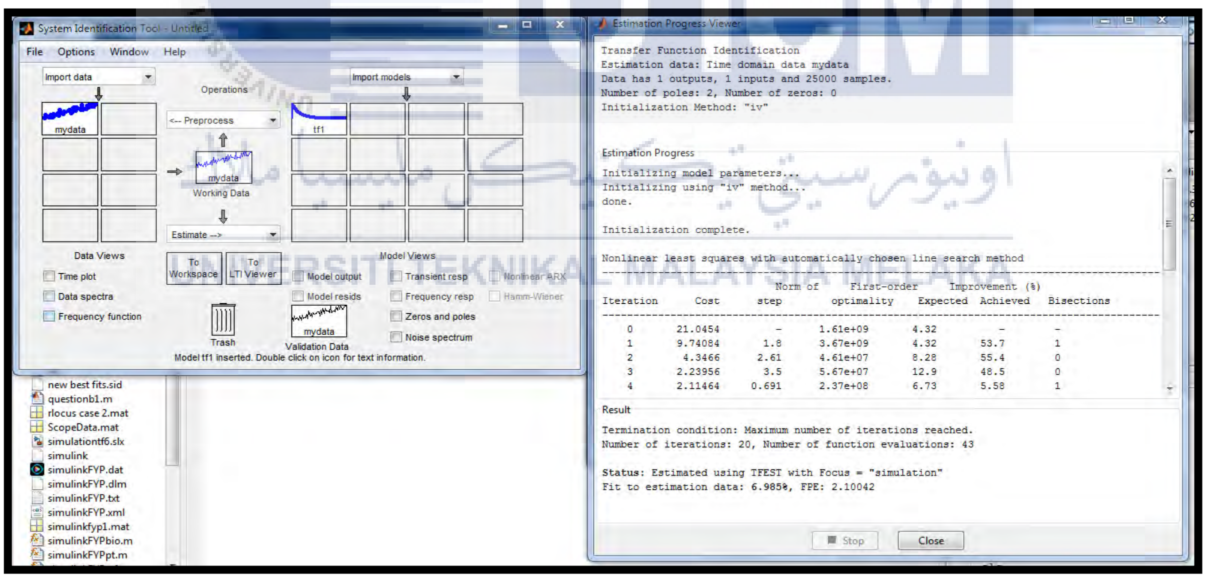


Figure 4.7: Transfer function model.

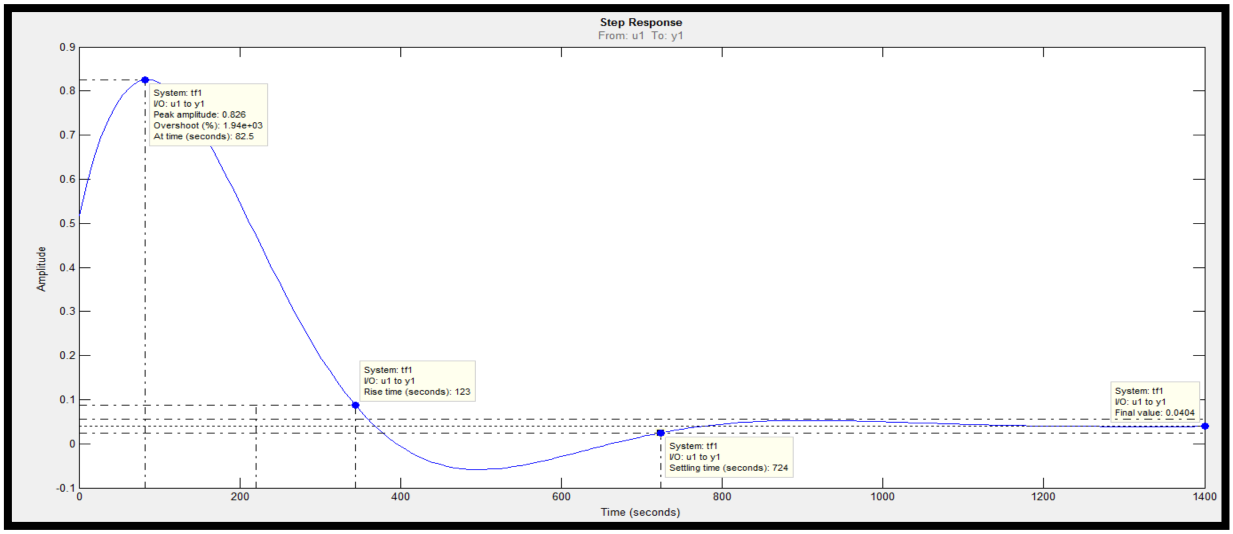


Figure 4.8: Step response for transfer function.

The transfer function:

$$Transfer\ function = \frac{0.5179s^2 + 0.01321s + 3.372e^{-6}}{s^2 + 0.01005s + 8.337e^{-5}}$$

Figure 4.2 shows that the position of the pendulum dancer increase over time. For this results, others parameter such as force caused by weight of dancer, F_W and spring loading of the minimum dancer at minimum position, F_L still no included in the simulation test. For this simulation, initial input is the torque of the motor and the output is the position of the pendulum dancer. However, the position of pendulum dancer still not in suitable position in this winding machine. To overcome this problem, the PID parameter will include in the closed-loop overall system.

After getting this open-loop response, auto tuner PID was used to tuning the transfer function to get the value for K_P, K_I, and K_D. Figure 4.9 is block diagram that used in tuning process.

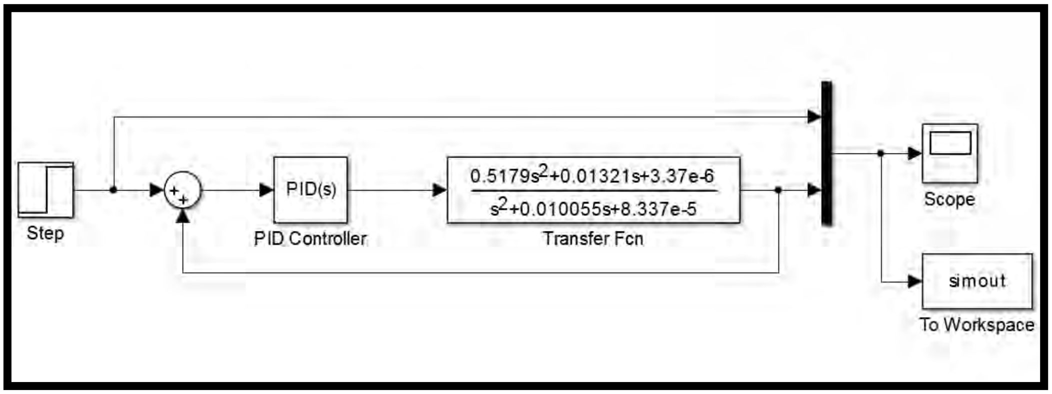


Figure 4.9: Block diagram of tuning process.

The results of tuning is used implement in inverter parameter which is to set the value of PID controller into the system. Figure 4.10 shows that the transient response after tuning.

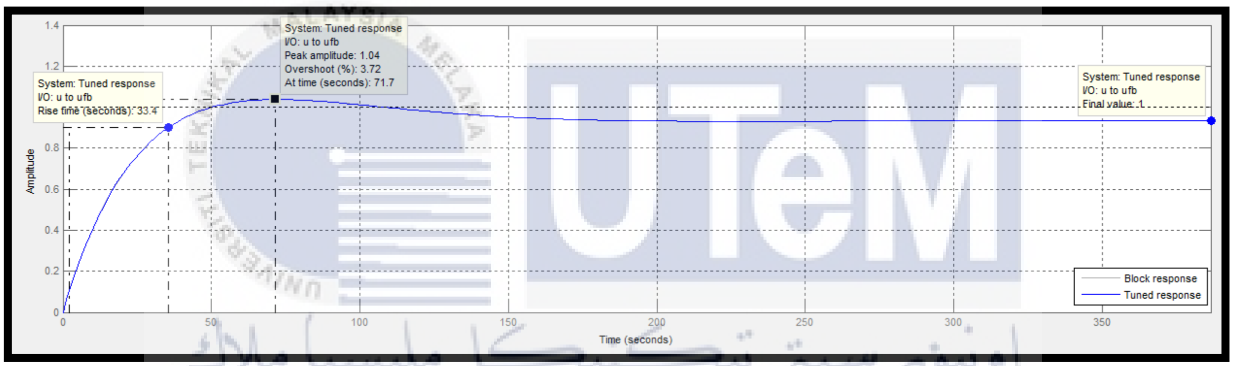


Figure 4.10: Transient response after tuning.

4.2 PID Controller Results (Experiment Test)

After implement the value of PID that get from open-loop response, testing on plant was testing for several type of condition of speed of motor when without PID and after adding the PID value. The PID work based on the sensor that detect the changes of the pendulum dancer in system. The PID used to control and adjust the speed of the motor. The PID give the signal or command to the PLC based system when the change of the tension is detected by the MIDORI sensor. The PLC will control the speed of the motor when change of the pendulum dancer is detected. When the dancer is move upward, the speed of motor will speed up. Meanwhile, when the dancer moves downward, the speed of the motor will become slow. The speed of the motor work in the range of speed that suitable for the EDM wire. During the experiment, the pendulum dancer needs to start from 20° in order to maintain proper tension of wire. Several parameter should be considered in this experiment such as speed of motor, value of PID and tension of wire.

Several experiment are tested to test the speed of motor that required to maintain the position of pendulum dancer and maintain the tension of wire. The experiment was tested with low and high type of speed. For condition of Motor 1 is setup for three condition which are low speed, middle speed and high speed. In low condition, speed was set in values (20Hz, 15Hz, 10Hz), meanwhile when middle speed condition is set (30Hz, 20Hz, 10Hz) and high speed condition when speed set to (60Hz, 40Hz, 20Hz). Different with Motor 2 which is only have two type of speed where low speed in 20Hz and high speed in 50Hz. In this experiment, micro box was used to collect the data for position of pendulum dancer. All the graph were shows of the position of pendulum dancer in difference type of speed.

Firstly, winder tension system was tested when no PID implement in the plant. Figure 4.11 and Figure 4.12 shows the graph of position of pendulum dancer when speed of Motor 2 high and low without PID.

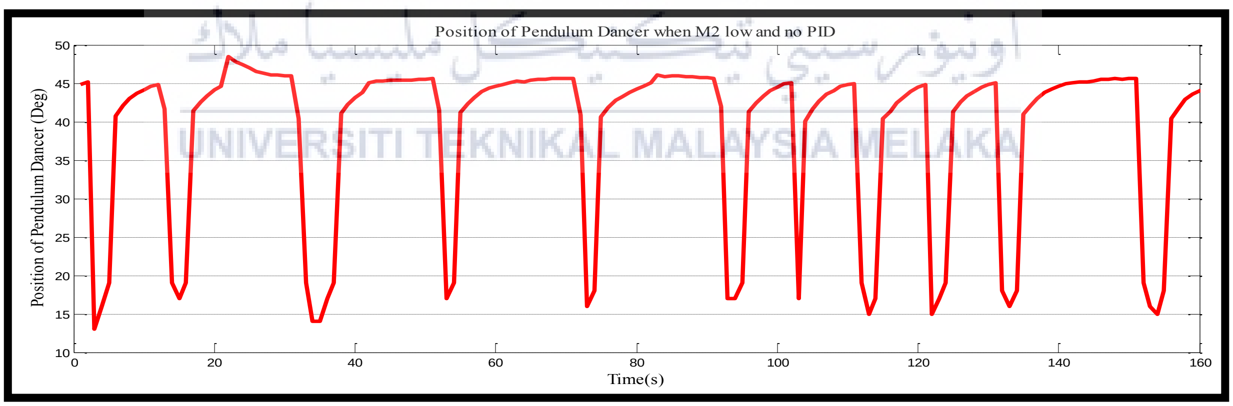


Figure 4.11: Position of pendulum dancer when M2 low and no PID.

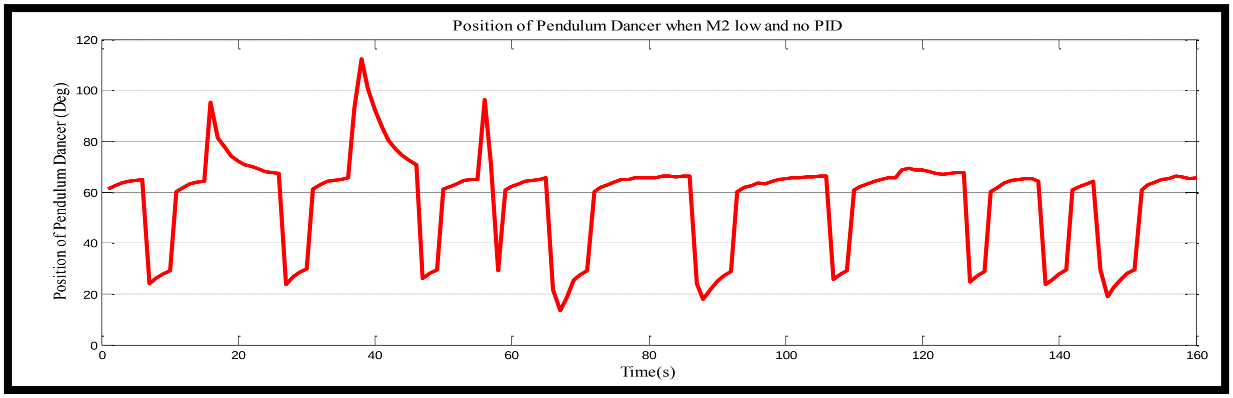


Figure 4.12: Position of pendulum dancer when M2 high and no PID.

For Figure 4.11, the range of this condition is 30 degree. According to this graph, it show that the pendulum dancer is take a large degree to maintain the position. This is because, when Motor 2 in low speed and Motor 1 in high speed, the Motor 1 give more wire to take up by Motor 2. So that, when position of pendulum dancer in max condition, Motor 1 give run in high speed to low the position, otherwise when position of pendulum dancer in min condition, Motor 1 give low speed to up the position.

For Figure 4.12, the range for this condition is 40 degree. From starting plant run, the pendulum dancer up until above 100 degree, then it consistent between 20 degree to 40 degree. The range for this condition is 40 degree. From starting plant run, the pendulum dancer up until above 100 degree, then it consistent between 20 degree to 40 degree. The degree of dancer was explained detail by figure in appendix part.

From both graph, it shows that when no PID controller implement in system it give the large difference degree to make the wire stable but still not proper for tension of wire run. So that, next graph shows that the result of position of pendulum dancer when the plant was implement the PID controller in several type of condition. The condition was explained in form of table for each graph.

Table 4.1: Condition of experiment with PID (condition 1)

Position of Pendulum Dancer when M2 low with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = Pr.4 (20 Hz), Pr.5 (15 Hz), Pr.6 (10 Hz)
4. Motor 2 = 20 Hz

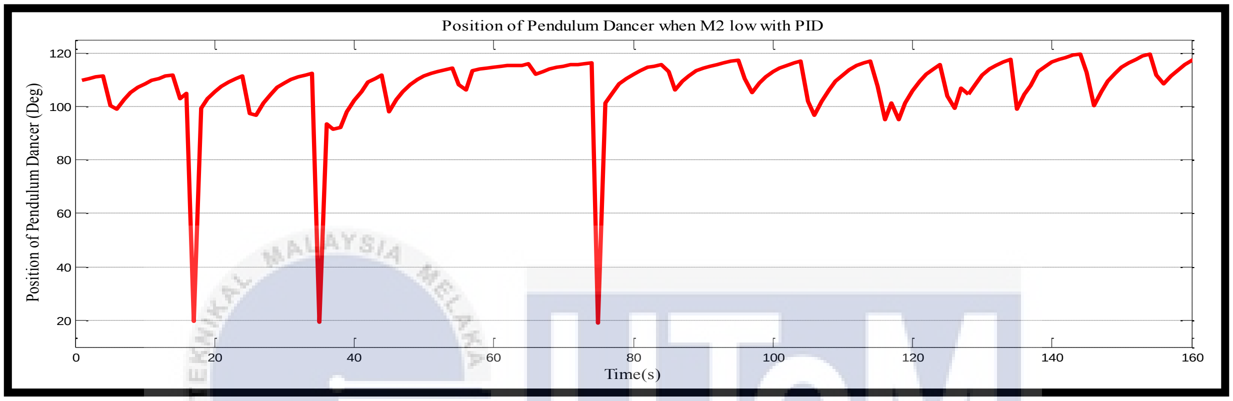


Figure 4.13: Position of Pendulum Dancer when M2 low with PID (condition 1).

The range for this condition is 20 degree. After put the PID controller, results give more improvement. For this condition, M2 is in low speed and M1 in low speed. The position of pendulum dancer is change the position above 90 degree and consistent between 100 degree to 120 degree.

Table 4.2: Condition of experiment with PID (condition 2)

Position of Pendulum Dancer when M2 low with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = Pr.4 (30 Hz), Pr.5 (20 Hz), Pr.6 (10 Hz)
4. Motor 2 = 20 Hz

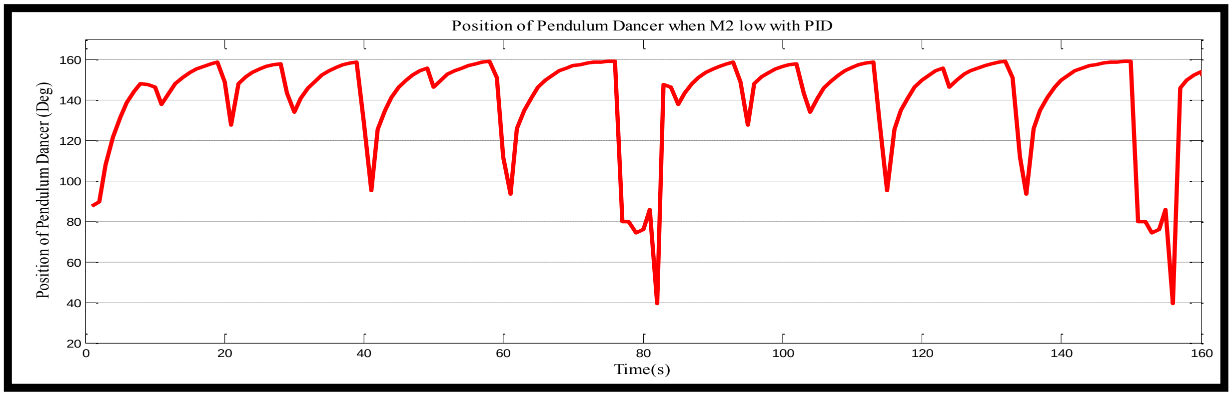


Figure 4.14: Position of Pendulum Dancer when M2 low with PID ((condition 2).

The range for this condition is 30 degree. After put the PID controller, results give more improvement. For this condition, M2 is in low speed and M1 in middle speed. The pendulum dancer start with up until above 140 degree and consistent between 130 degree to 160 degree. But due to limitation of plant, the pendulum dancer have some problem when run but take a few second to the suitable position back.

Table 4.3: Condition of experiment with PID (condition 3)

Position of Pendulum Dancer when M2 low with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = Pr.4 (60 Hz), Pr.5 (40 Hz), Pr.6 (20 Hz)
4. Motor 2 = 20 Hz

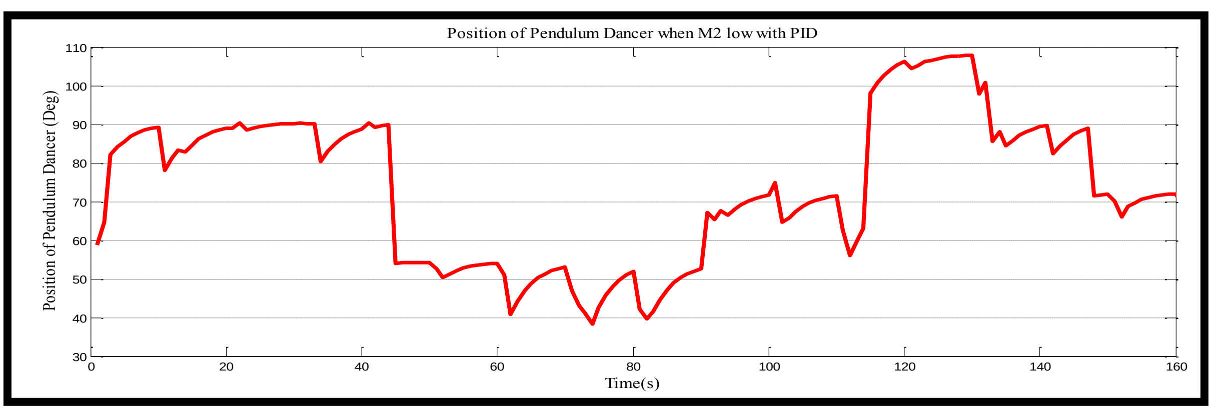


Figure 4.15: Position of Pendulum Dancer when M2 low with PID (condition 3).

The range for this condition is 10 degree. After put the PID controller, results give more improvement. For this condition, M2 is in low speed and M1 in high speed. The pendulum dancer start at 60 degree and up to 90 degree. The position of pendulum dancer is consistent at 80 degree to 90 degree. The system have a several limitation when experiment but the pendulum dancer success to maintain back the position.

Table 4.4: Condition of experiment with PID (condition 4)

Position of Pendulum Dancer when M2 high with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = Pr.4 (20 Hz), Pr.5 (15 Hz), Pr.6 (10 Hz)
4. Motor 2 = 50 Hz

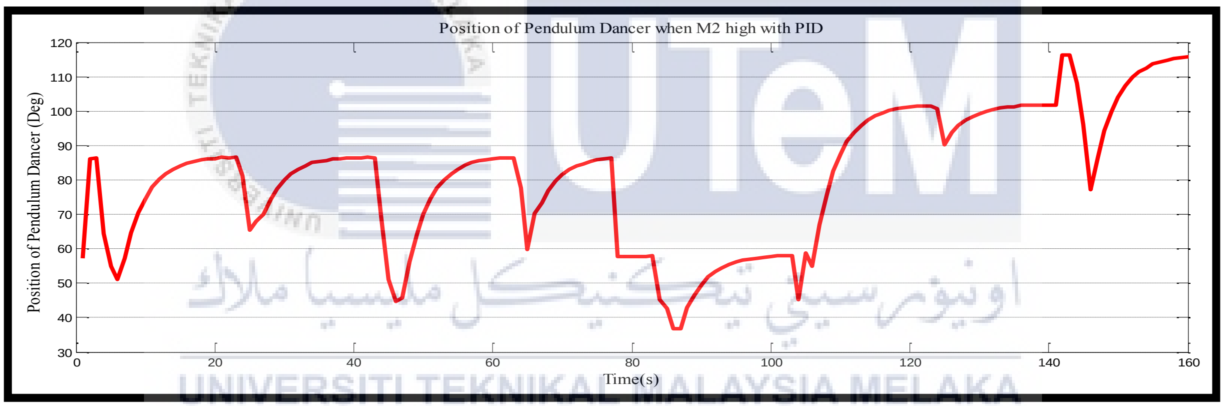


Figure 4.16: Position of Pendulum Dancer when M2 high with PID (condition 4).

The range for this condition is 35 degree but at certain time it give difference range. After put the PID controller, results give more improvement. For this condition, M2 is in high speed and M1 in low speed. For this condition, pendulum dancer cannot run properly because of speed of M2 higher than M1. It became unstable condition in graph but in experiment it still can run but the wire become tight at certain time.

Table 4.5: Condition of experiment with PID (condition 5)

Position of Pendulum Dancer when M2 high with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = Pr.4 (30 Hz), Pr.5 (20 Hz), Pr.6 (10 Hz)
4. Motor 2 = 50 Hz

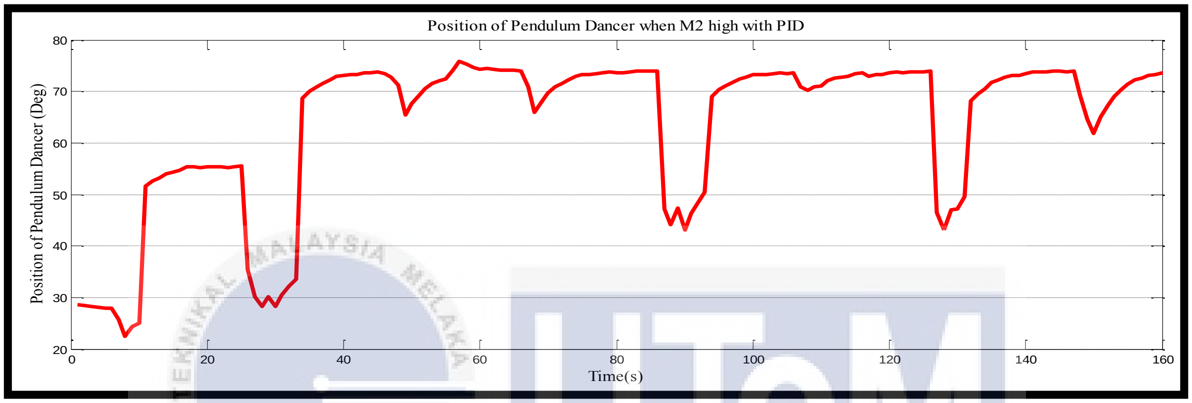


Figure 4.17: Position of Pendulum Dancer when M2 high with PID (condition 5).

The range for this condition is 10 degree. After put the PID controller, results give some improvement. For this condition, M2 is in high speed and M1 in middle speed. But at certain time, the position is down and up in large degree due to limitation of experiment. The consistent of position in between 65 degree to 75 degree.

Table 4.6: Condition of experiment with PID (condition 6)

Position of Pendulum Dancer when M2 high with PID
1. P=0.00667, I=20s, D=10s, Set point=20
2. Time = 160s
3. Motor 1 = = Pr.4 (60 Hz), Pr.5 (40 Hz), Pr.6 (20 Hz)
4. Motor 2 = 50 Hz

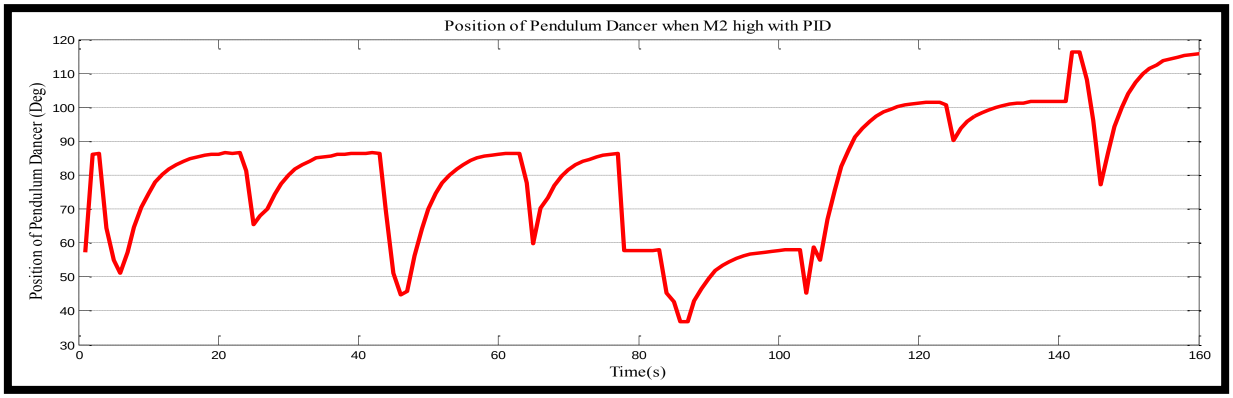


Figure 4.18: Position of Pendulum Dancer when M2 high with PID (condition 6).

The range for this condition is 25 degree. After put the PID controller, results give more improvement. For this condition, M2 is in high speed and M1 in high speed. The motion of pendulum dancer more stable because the speed for both motor can give the faster feedback. Due to this condition, at certain time it have some problem in experimental but pendulum dancer still run to get the best consistent degree to maintain and make it stable.

Basically, the pendulum dancer will remain consistent at angle 2 or 3 to angle 4 or 5. The range angle 3 is the suitable position for pendulum dancer to get the proper tension of wire.

As the result, during the experiment to get the suitable position of pendulum dancer due to speed of motor of Motor 1 and Motor 2 which is un-winder process and re-winder process respectively. Figure 4.16 shows the overall plant of winder tension system.

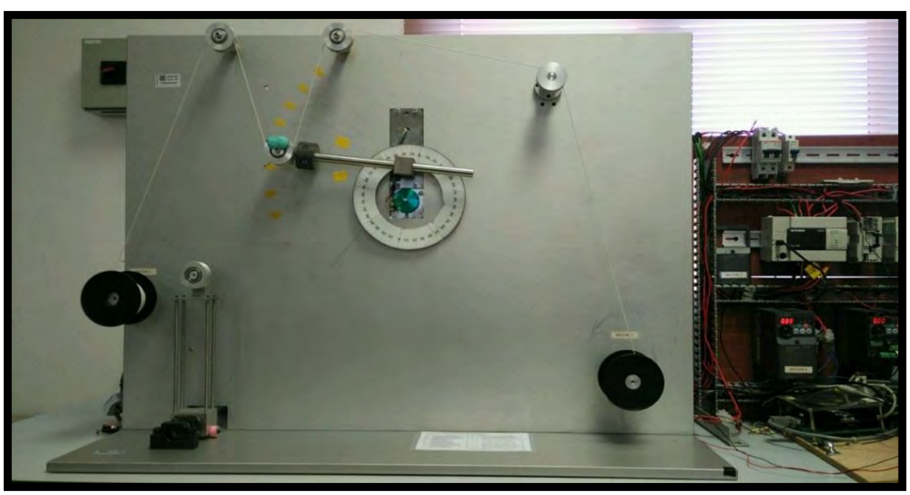


Figure 4.19: Overall plant of winder tension system.

4.3 PLC Ladder Diagram

For the GX-Developer ladder diagram, the operation state is shown by the green highlighting colour at PLC hardware interface. It can provide the monitoring operation without connecting the PLC with the system hardware to observe the operation. We can transfer the PLC instruction to PLC hardware by using GX-Developer.

First, all the instructions are in open condition but only the X001 (stop button) in close condition. After the transfer setup done, open the power supply and push X000 (start button) to start the program. After the start button ON, M0 (motor 1) start moving which is un-winder roller. Motor 1 will move forward. After that, M1 (motor 2) will start move forward in medium speed.

For Motor 1, there are three condition of speed that motor will running according to position of pendulum dancer which is low, medium and high speed. X002 and X003 are the limit switch for ball screw whether move in clockwise or anticlockwise. All the operation will continuously running until stop button push ON. The ladder diagram is present in appendix.

CHAPTER 5

CONCLUSION AND FUTURE WORK

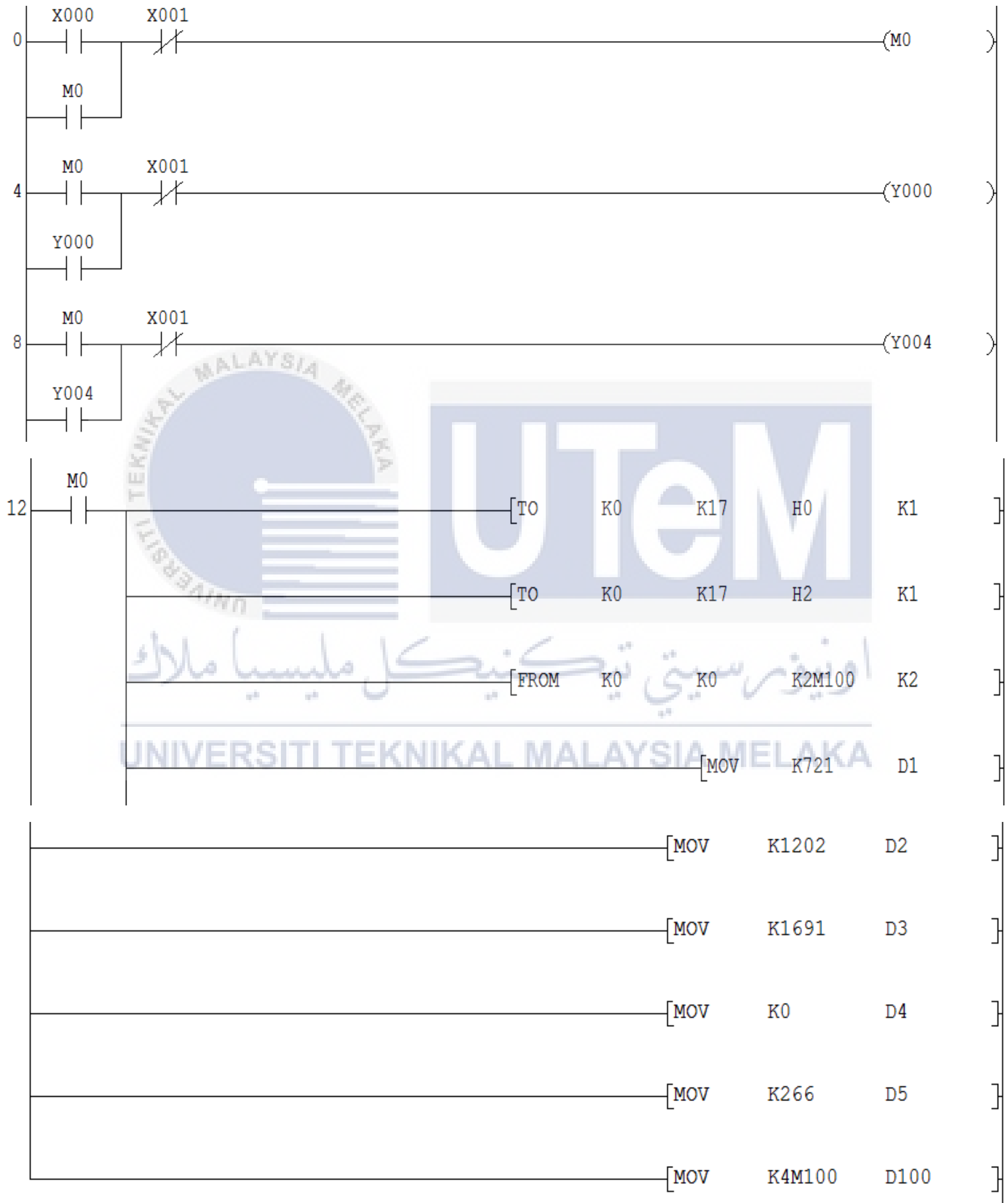
Programmable Logic Control (PLC) is the important and popular system that been applied in industry field. PLC system has a lot benefit which can help human to control system easier and faster for the complex system. Thus, with this system control, any process can work smoothly. This PLC system has a lot of potential which can be explored to make it more sophisticated in the future. Otherwise, when PID controller implemented in this winder system, the performance is better than before.

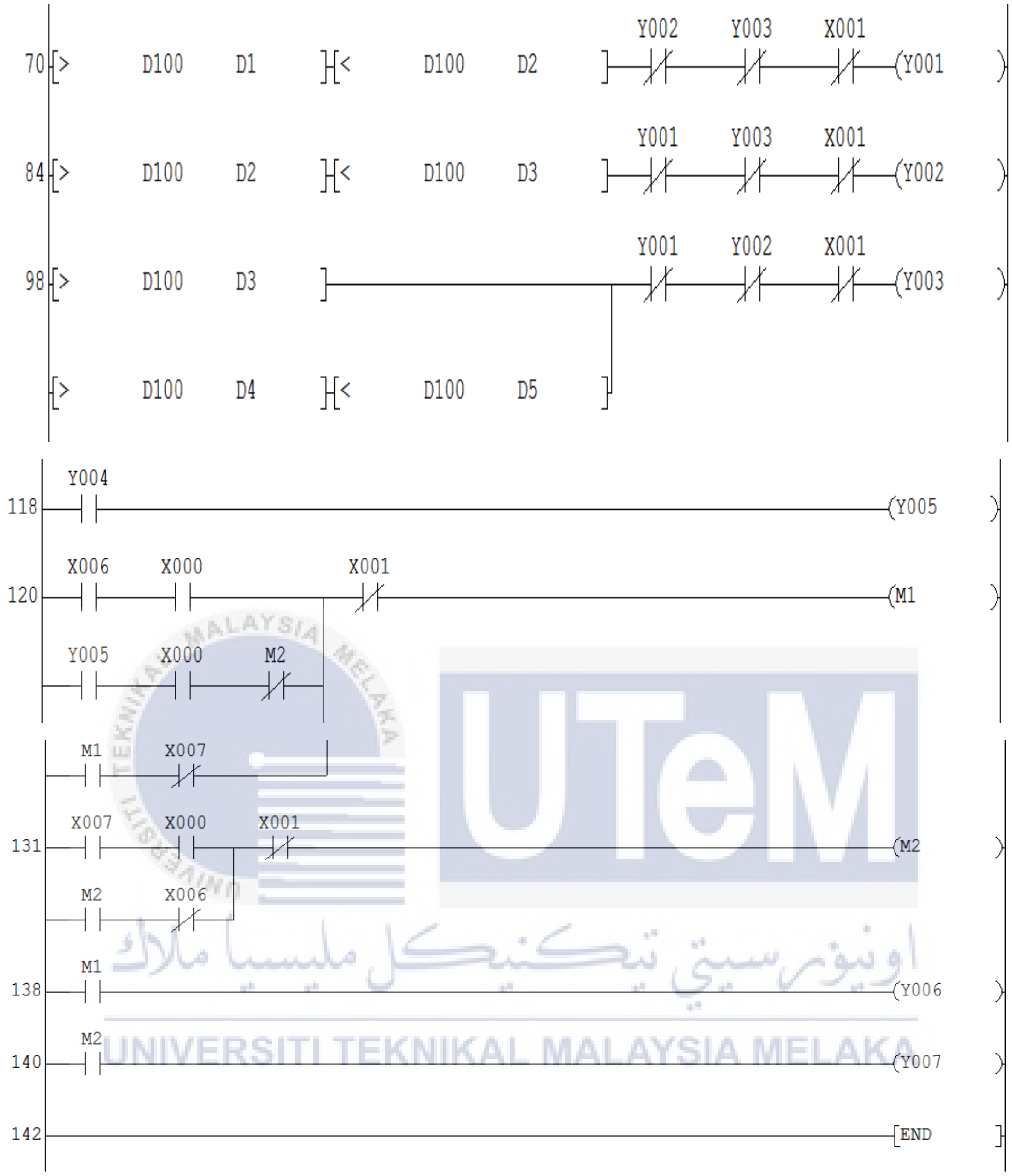
PID controller give to the system to make it more stable and consistent. From analysis and observation when run the experimental, the system run smoothly and the issue of loosen of wire decrease. This is because, the controller have given a feedback to the speed system according to position of pendulum dancer. Due to experimental results after implement PID, the optimum range for position of pendulum dancer is starting 60° to 85°. The position sensor that uses to control the speed of the motor is the MIDORI Green Pot Precision Angle sensor.

At the end of this project, the objectives are achieved. The comparison of technique of tuning controller have been proved in result chapter. For the next coming work, the system should have tuning by fuzzy controller technique for make the system more consistent due to their function.

APPENDIX

A. Ladder diagram for PLC




70 [> D100 D1][< D100 D2] Y002 Y003 X001 (Y001)
84 [> D100 D2][< D100 D3] Y001 Y003 X001 (Y002)
98 [> D100 D3] Y001 Y002 X001 (Y003)
[> D100 D4][< D100 D5]
118 Y004 (Y005)
120 X006 X000 X001 (M1)
Y005 X000 M2
M1 X007
131 X007 X000 X001 (M2)
M2 X006
138 M1 (Y006)
140 M2 (Y007)
142 [END]

B. Hardware (Winder tension system)

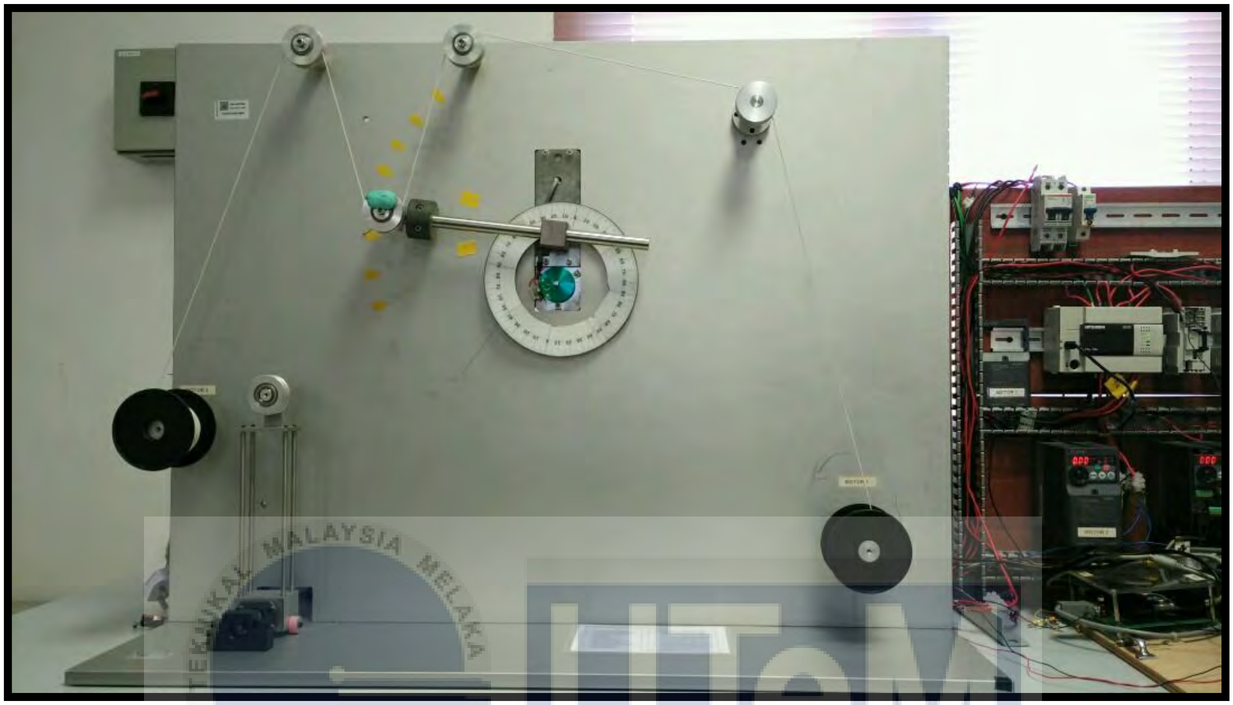


Figure (a): Overall winder tension system.

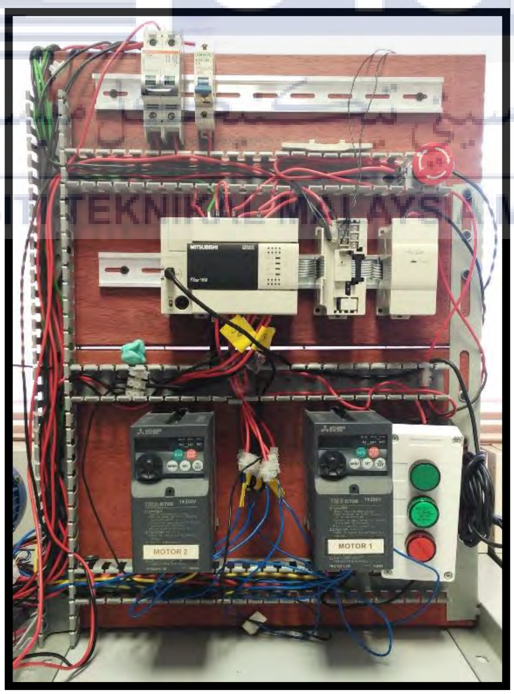


Figure (b): Control panel.

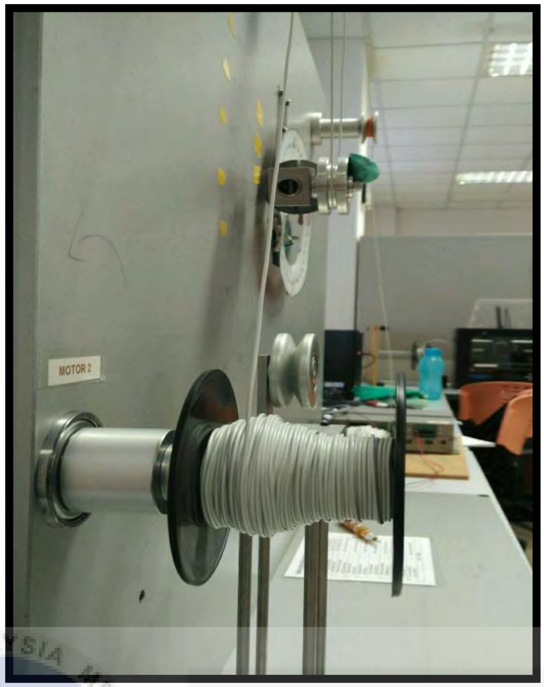


Figure (c): Re-winder process part.

Figure (d): Un-winder process part.

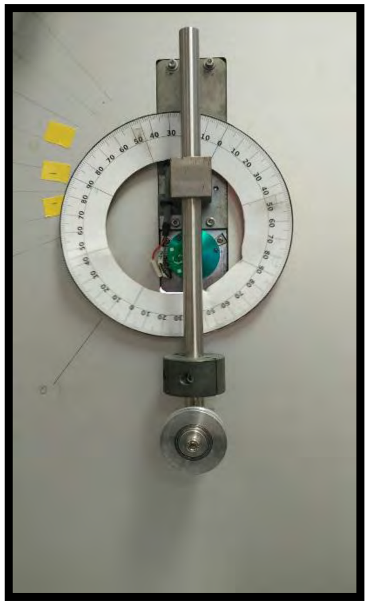


Figure (e): Pendulum dancer.

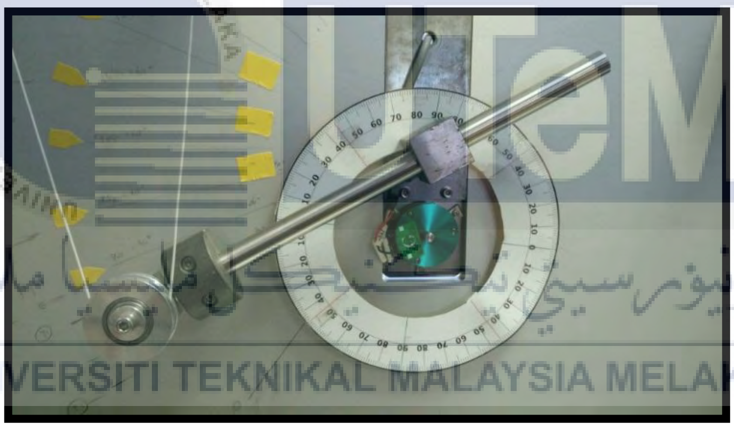


Figure (f): The suitable position of pendulum dancer (Angle 3).

Figure (g): PLC interface.

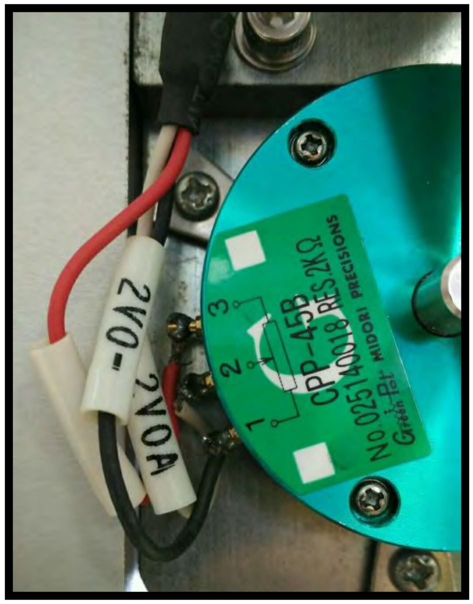


Figure (h): Midori Precisions Sensor.

Figure (i): Motor 1 and Motor 2.

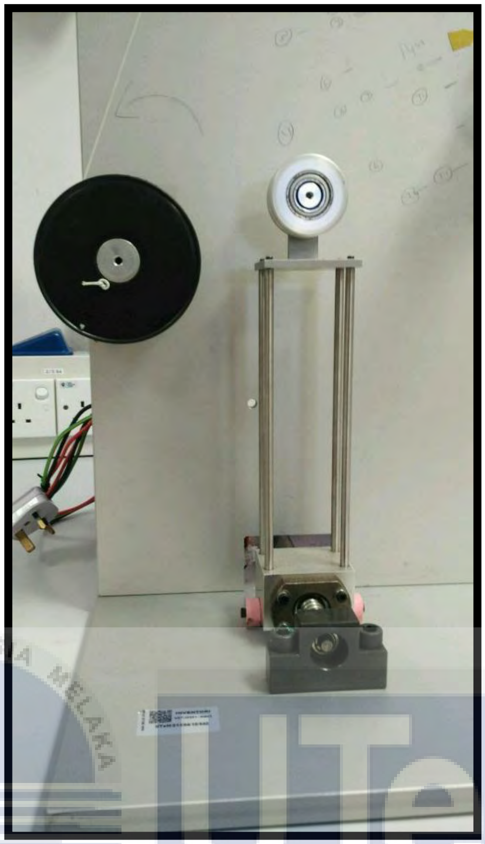


Figure (j): Ball Screw part.

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