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Electrical and Computer Engineering

AUTOMATIC TURBINE SPEED CONTROL USING INTEGER AND FRACTIONAL ORDER PID CONTROLLER BASED ON GENETIC ALGORITHM

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Master Thesis

Supervisor

Prof. Dr. Osman Nuri Ucan

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by

Ahmed Ayan Obed

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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Ahmed Ayan Obed

DEDICATION

In the name of God, The Most Gracious, The Most Merciful.

I dedicate the fruit of my success and my getting on masters degree to who she has given me tenderness and continued support in all areas of my life. My dear mother, I ask God to prolong her life and give her full health and wellness, to who is I learned from him patience and endurance in order to raise the level of scientific, God save him and gave him health and wellness. And to my brothers and sisters and their children who are source my strength. And to the open roses, by their scent are give me the patience and strength, my children (Ehab, Jannah and Razan) God save them and keep them near me, to my friends, and everyone who helped me and wished me the good.

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ABSTRACT

AUTOMATIC TURBINE SPEED CONTROL USING INTEGER AND FRACTIONAL ORDER PID CONTROLLER BASED ON GENETIC ALGORITHM.

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In the field of automatic control, FOPID and PID controllers are used in all areas of industrial work. From small operations to large operations, their work in different processes is very important for precision work and reduced effort, such as refineries and other factories. Using PID or FOPID at work is similar to routine work. So, we think about how we can improve these controllers and choose the best among them. We benefit greatly from the world of computing by choosing a way to develop PID and FOPID, and to develop their performance in a good way. In this research, PID and FOPID will be adjusted using the genetic algorithm, in order to know the best results for each, and compare them, using each of them to control the speed of the steam turbine, the process is performed by computer simulation by implementing a program in Matlab, then we compare the best results between PID and FOPID are analyzed and the results will be drawn from simulation and comparison for adoption in practical application, such as computer control systems.

Keywords: PID Controller, FOPID Controller, Genetic Algorithm, FOPID Controller Tuning, Matlab simulation

ÖZET

BUHAR TÜRBİNİ HIZININ GENETİK ALGORİTMAYA TABANLI PID MİKRODENETLEYİCİ KONTROLU

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FOPID ve PID kontrolerleri endüstriyel endüstrinin bir çok dalında kuilanılmaktadır Rofinerlerde, farklı fabrikalarda hassasiyeti arttırması, daha az emek harcanması nedeniyle kontrolörler sıkca uygulama alanı bulmaktadır PID ve FOPID işlemleri standart hale getirir. Genetik algoritma kullanılması halinde başarım artmaktadır. Uygulamaya dönük matlab yazılımı ile başarımlar karşılaştırılabilir hale gelmekredir.

Anahtar Kelimeler: PID Kontrolör, FOPIP Kontrolör, genetik algoritma, Matlab yazılım.

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LIST OF ABBREVIATIONS

SCADA	: Supervisory Control and Data Acquisition
HMI	: Human Machine Interface
PLC	: Programmable Logic Controller
DCS	: Distributed Control System
FOPTD	: First Order Plus Time Delay
SOPTD	: Second Order Plus Time Delay
PID	: Proportional-Integral-Derivative
FOPID	: Fractional Order Proportional-Integral-Derivative
IAE	: Integral Absolute Error
ISE	: Integral Square Error
ITAE	: Integral Time Absolute Error
ITSE	: Integral Time Square Error
HMI	: Human Machine Interface
HPV	: High Pressure Valves
RHV	: Re-Heater Valves
HP	: High Pressure
MP	: Medium Pressure
LP	: Low Pressure
Z-N	: Ziegler-Nichols

1. INTRODUCTION

Automation-control is important in all areas of life, whether in the industry or other areas, so it is necessary to use them in the best possible manner and to work on developing them and improving them to the best possible extent to give the best results in use, especially in the industrial field, because it is an area where equipment is used and loss of control causes risks, and for easing of employees to use equipment and reduce effort, time and cost [1,18].

Steam turbines are important and useful in the industrial field. A steam turbines are tools which are used for converting high-pressure stored steam energy into rotary energy, which can be used in various forms such as rotating power generators, pumps, compressors and other uses. Steam boilers supply hot steam to increase thermal efficiency. Steam turbines enable steam to be used in multiple phases using combined turbines. In combined turbines, all sections are on a single shaft with one generator to be controlled, the best method for perfect control is important. Controlling the speed of rotation and setting it at a certain speed can be done by controlling the amount of steam passing through a valve that reduces and increases the amount of steam. This process is done through the electronic programmed control, such as computer, PLC and other electronic control devices, and the same by receiving an electrical signal from the transmitter representing the rotation speed of the turbine and comparing it with the speed required to give a signal to the valve in order to reduce or increase the amount of flowing steam [2]. The criteria used to calculate the quality of the control process are response time and stability time. It is preferable to have a small time when the quality is compared among them on the basis of these times[3]. Different types of control methods such as PID, FOPID and others are applied to an electronic device for the sake of knowing which of them can give better results of control .

In this theses, PID and FOPID will be tuning by using the Genetic Algorithm (GA) and the best results for each of them[4]. By using each one of them to control the steam turbine[5], the process is done by simulating the computer by executing a program in Matlab then we will compare the best results Between PID and FOPID for the purpose of adoption in the application figure 1.1 shows the double-heating steam turbine used in the paper [6].

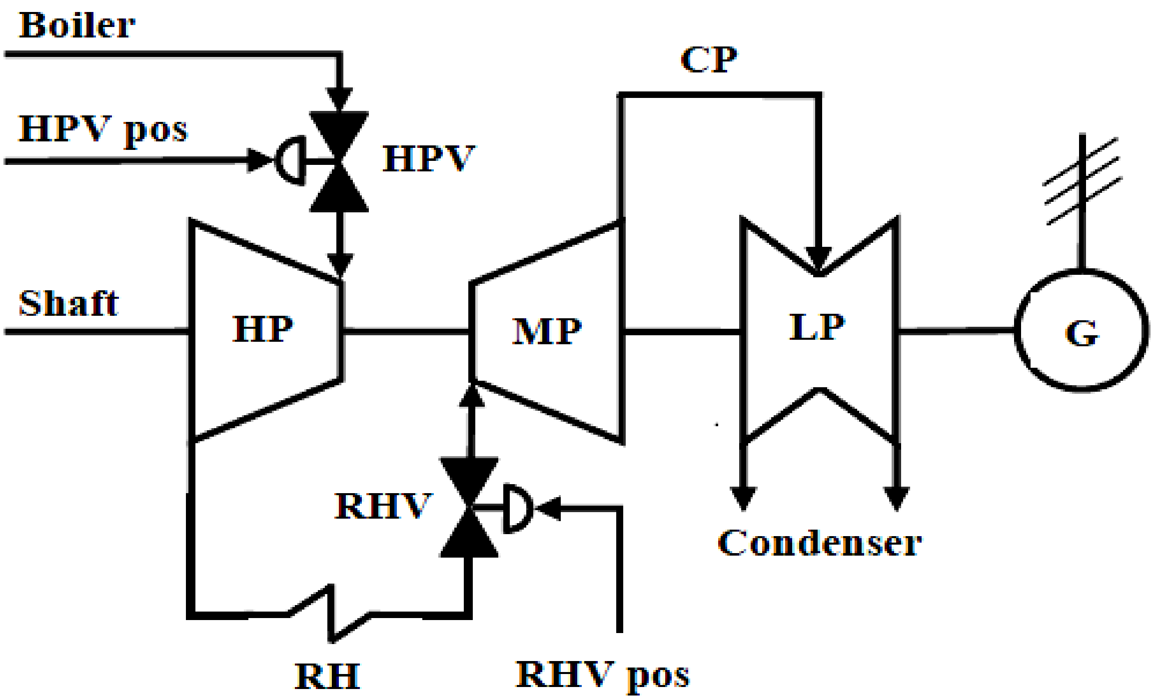

Figure 1.1: Double-heating steam turbine[6].

1.1 OVERVIEW

The history of control systems is presented and developed until the entry of the computer in the process of control, which proves to us the great difference shown by the ease of use and accuracy in the control operations that give them in the implementation of orders on the process to be controlled, and also reduced the cost of price and muscle effort and the number of workers , The aim of presenting the history of the development of control for the view and focus on computer control and its uses and the field of development to take advantage of in all areas of life and the most important in the industrial side. The process of control through the history of multiple stages, as follows[7,8]:

- The stage of manual control. At this stage, The main dependence on the human factor in the process of control is to open and close the valves depending on the consideration of the case of filling the reservoirs or determine the level of liquids and the height and decline of temperature measurements for reactors and other example of the process to be controlled is to determine the level of fluid in the reservoir. The control process is the eye, as the level sensor, which gives a signal to the brain that acts, as the control of the process which in turn gives a signal to the hand that closes or open the valve that represents the Final Control Element (FCE), as shown in figure 1.2 [9].

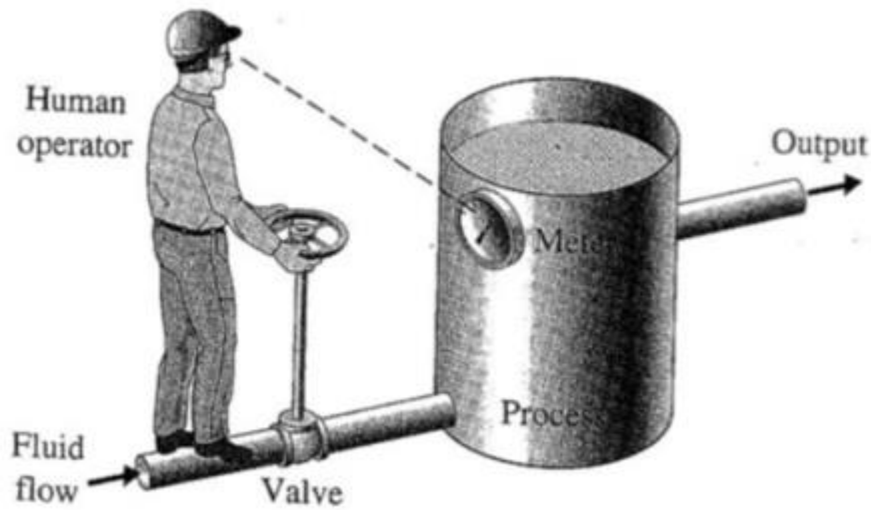

Figure 1.2: The operator acts as a controller [9].

- Mechanical control stage: Mechanical parts are used to achieve the control process and is a mechanical control process, because it mechanically eliminates the effort of the operator actually for example the raft is used to measure the level of fluid and the associated arm to close or open the line of the fluid that represents control. The most important process of mechanical control is the process The use of compressed air(Pneumatic control) is used to influence the devices, as well as to transfer the signal to the control room, Which is the amount of pressure to express the value of the measurement is used to influence the controlled mechanical controls to show the value of pressure to a state can be used to know Measured value The mechanic controller can also send a pressure signal based on the signal received to influence a valve or other controlled parts and there are other mechanical stages such as Hydraulic Control.

The stages of control have evolved into a new phase

- Electronic control stage: At this stage there was a big breakthrough in the process of control of the way it has the speed of transmission of the signal and Sensitivity to changes. It has become an introduction to electronic and software development. Electric sensors have been used to transmit the signal after conversion from natural quantities to electrical quantities. The value to be expressed can be represented by current or voltages. When moving the signal from the location of the segment to be measured by cables to the control room, which can be away from the work site to be processed and used by the electronic controller, which shows us the result of reading on the real form of quantity and also sends a signal to achieve control. In this part of the electronic process Analog signals were used in electrical devices used in the control process [1]. This conversion in the control process helped reduce the strain and cost best than the mechanical control phase and also increase the accuracy of the control, as shown in figure 1.3 [1].

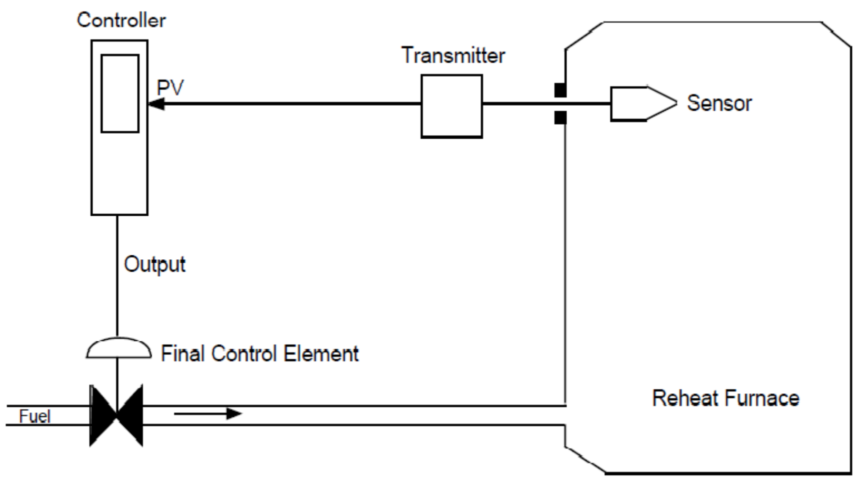

Figure 1.3: Electronic control system[9].

- The stage of computer control or methods of digital devices, which is we focus on and solidify our attention, which is the focus of this theses.

1.1.1 Principles of Digital Control

Automatic Is the automatic control of machines, so that the sequence of operations according to the way they work for control by custom controls, a way to facilitate the work of operators to produce more effectively.

1.1.1.1 Automatic types

Fixed Automation

Used when the work of the machine is intended for a fixed process, when it performs certain and fixed purposes, for example oil refining operations.

Programmable automation

A system in which the machine can produce multiple forms of designs on the same machine, so you can change the sequence and properties of operations related to its work programmatically, where the control is changed by a special program. For example, Digital Control (NC).

Flexible automation

It is an extension of the programmable machine system so that there is no wasted time in the process Reprogramming, used when flexible operations, such as control Digital Computer (CNC).

1.1.1.2 Types of Control Systems

Numerical Control (NC)

It determines the appropriate cutting tools, cutting speeds, proper operating procedures and arranging the operation of the machine, All based on the worker's experience, knowledge and personal skills.

Computer Numerical Control CNC

Is a control system of the machine by a computer connected to digital control, the computer contains a memory to save programs. Machine Control Unit (MCU) The control unit compares the operation of the machine with the operation program and processing the error if found. The controller also contains programs stored for all machine functions, and does not remove these programs when the machine stops working and the program can be restarted frequently for each machine condition available. The computer has a keyboard with letters and numbers to enter Programming It has a screen that displays the driver and the path of the tool Path (Tool Path) Output, Through which errors can be identified in the driver.

Direct Numerical Control (DNC)

Direct Numerical Control: A set of digitally controlled playback machines is connected to a central computer by a network direct connection. The computer contains programs for each machine so that providing each machine with the required program in a timely manner, Which provides the machines with all the necessary data to follow the control, moving the program to produce the operator from the computer memory directly to the machine specified. This process is known, as direct digital control (DNC).

PLC is an important part of information exchange and application of methods, Which has become a high-performance PLC in the CNC control system.

1.1.2 Some Subsystems in PLC Technology

Human Machine Interface. HMI

It is governed by a rule between the operator and the control system that facilitates the viewing of the controlled process. It is designed programmatically by programs dedicated to industrial graphics and displays the values of controlled variables. It can also change operating positions and control processes, which are connected to control units such as PLC and DCS, for the purpose of receiving and transmitting data**.**

SCADA Systems

Interfaces that allow for direct interaction between humans and the control system and to achieve this purpose requires by high-capacity programs to achieve the advantages provided by these interfaces, the system reflects the process of Supervisory Control and Data Acquisition (SCADA) that is an excellent, Executed this task by PLC that it allows control of its associated units completely control by remote computer from the workplace [19,22].

DCS

It is an industrial control system in which tasks are distributed rather than concentrated in one location. There are many industrial applications of this system such as control of oil and gas refineries, Nuclear reactors and pharmaceutical factories, as shown in figure 1.4.

There are many companies specializing in the design of DCS systems, which design their own program to display programming and installation, the most famous of these companies Yokogawa, Honeywell and Rockwell.

There are three levels of control for DCS It is usually carried out in the factory The structure uses three levels: Operation ¨Level, a Control Level, and a Field Level [11,12].

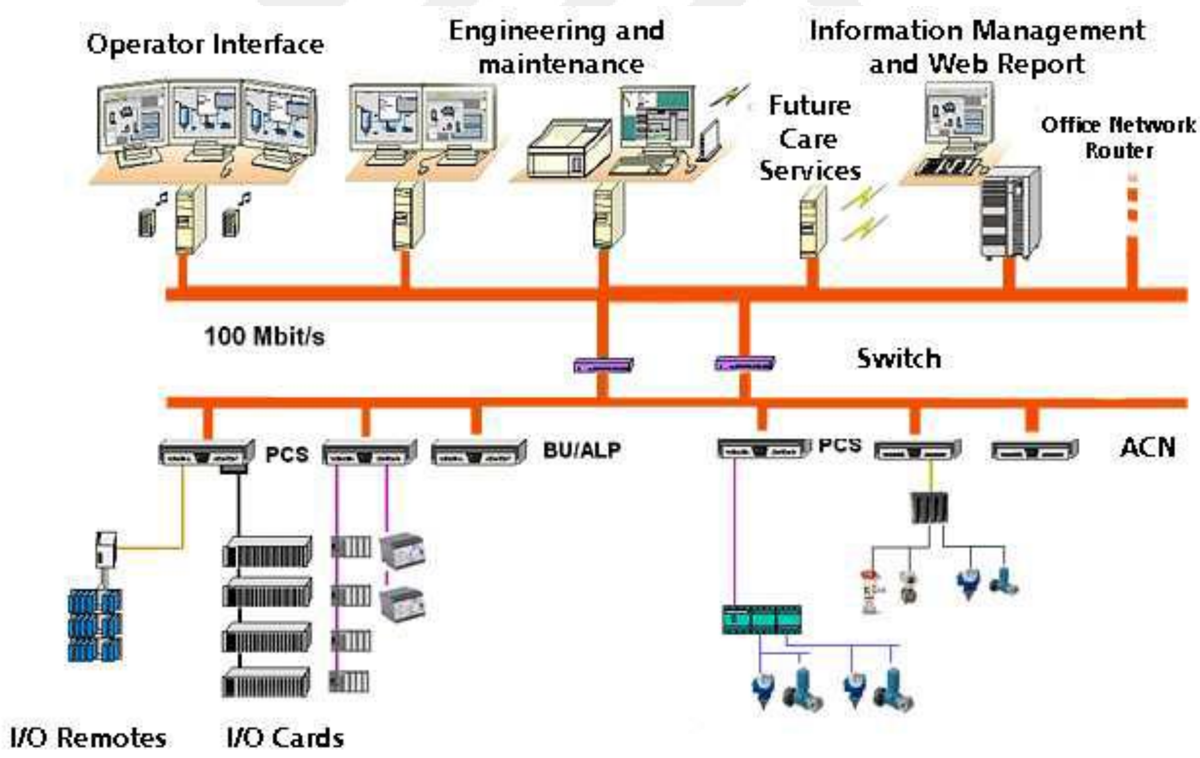

Figure 1.4: Distributed Control System [10].

1.2 PROBLEM STATEMENTS

The steam turbine is a mechanical device that uses the thermal energy and pressure of the boiler steam and turns it into rotational motor energy invented by the Charles Algernon Parsons in 1884. The turbine has many uses, including the use of compressors, pumps and power generators which are the most important uses. Electricity is powered by steam turbines. Nuclear, oil and coal plants operate on the same principle, as they convert heat energy from thermal boilers to high pressure steam, through which the turbine is rotated and the alternator is rotated. The control of the speed of rotation is very important, because turbine blades need to regulate the flow of steam by a valve that controls the amount of steam. At first you need a low speed to control the speed by partial opening of the valve, the speed of rotation is increasing, leading to a severe collapse and damage to the turbine, which is expensive. The speed of the turbine is controlled depending on the load, whether increase or decrease to ensure that the speed of rotation is increasing. Accelerate a steady rotation, because it is low The speed of the load increases. This requires reducing the opening of the valve to reduce the speed. Also, when the load increases, the speed decreases. The valve opening is required to increase the speed. This process is a programmed control designed in a way that is taken from the behavior of the turbine according to speed sensor. The better it is, the more we need a control that responds in a short time to the emergency conditions on the speed of the turbine to maintain it and the outputs resulting from its rotation whether it is the production of electricity or pressure or flow ... etc, in electricity, for example, the speed of the turbine is proportional to the frequency of external power. There are types of control methods that require the knowledge of the controlling who gives better results in control. In this thesis. The dominant FOPID and the dominant PID were taken and their performance was improved by the genetic algorithm to control the two-phase turbine and compare their respective results, this is done by simulation in the Matlab program.

1.3 PROJECT'S OBJECTIVES

The aim of this study is to improve and select the best process to control on the speed of the steam turbine because of its control of the importance of the preservation of the turbine from damage and the risks resulting from poor control of people and equipment. This study looks for a good way to control by controlling the genetic algorithm that Is a distinctive method of improvement and to obtain the values of the variables used in the control to give the best results, and compare the results between each control for the purpose of knowing the most appropriate in the control of the turbine. In the dominant PID and FOPID study, they were used in the computer genetic algorithm and simulated by a program that is designed in the matlab. The simulation gives us results for each control in terms of the response time of the turbine on the speed of the turbine and the time to process it, making it easier for the operators to run the turbine and control. And the possibility of using computer control that reduces the cost and number of employees.

1.4 THESIS STRUCTURE

This thesis examines the tuning of the PID and FOPID controllers using the genetic algorithm to make them give the best results, when they use to control the steam turbine and then compare the results for the purpose of finding out the best. Consists of five chapters: first chapter consists of introductory introduction to the thesis, a general overview of the history of the development of control systems and focus on computer control, The problem of research, The goal of the thesis. Second Chapter contains Define the PLC, as most prominent device in Practical and the presentation and discussion of previous studies. Third Chapter contains scientific definitions, as Genetic Algorithm, PID controller and Fractional Order PID, Simulation process. Fourth Chapter Presentation of the results, Fifth Chapter Conclusions and future work, sixth Chapter our contribution.

2. SECOND CHAPTER

2.1 THE MOST PROMINENT DEVICE IN PRACTICAL

Programmable Logic Controllers (PLCs), PLC is a programmed control device, it is from the computer family, and its operation depends on the input to make the decision on the outputs by automatic operation, as shown in Figure 2.1. PLC is used in industrial and commercial applications.

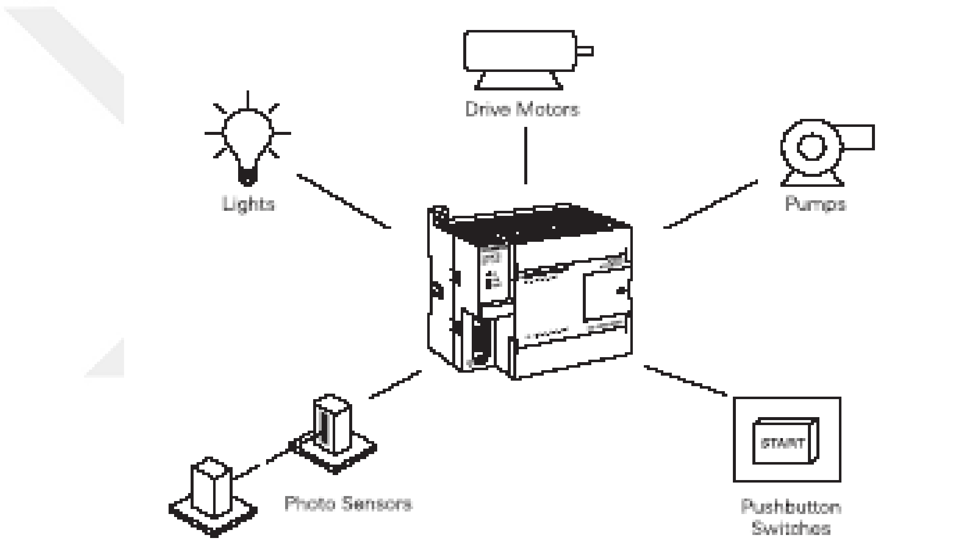

Figure 2.1: PLC control[65].

2.1.1 Basic PLC Working

The plc consists of a digital processor and an input model that receive signals from the field and these signals are either digital or analog, and It contains the output model. PLC's work involves receiving the signal from the field by input models, and then converting it to a digital signal that the processor can handle and process it by a program stored in the memory according to the required process and then convert it to the analog signal and transferred it outputted through the output model to the field for the purpose of controlling, the part to be controlled, as shown in Figure 2.2. It includes an operator interface that can display and enter information on process parameters.

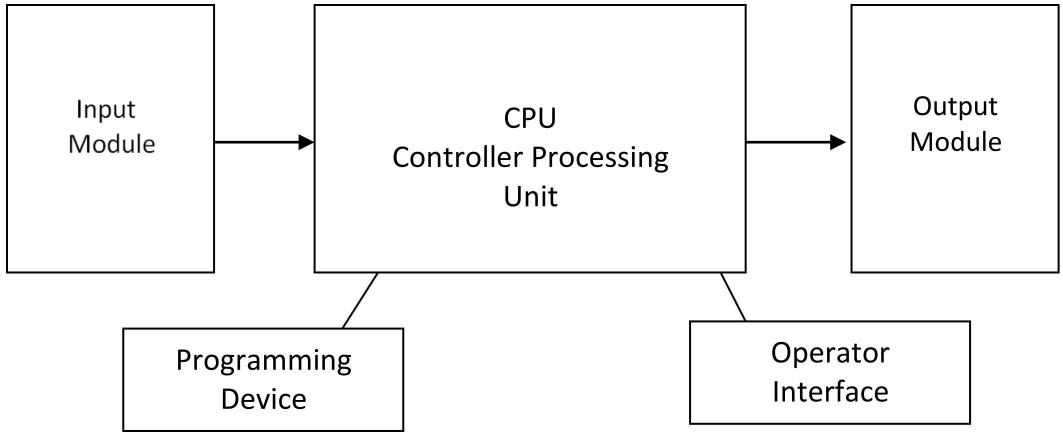

Figure 2.2: PLC component[65].

The PLC enables the use of pushbuttons that are connected to the input model for use in switching on and off motors, as shown in Figure 2.3.

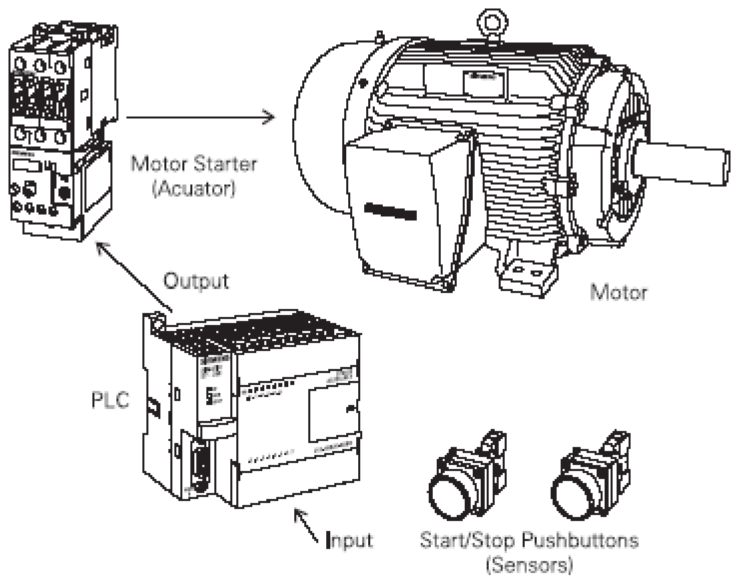

Figure 2.3: PLC pushbuttons[65].

2.1.2 PLCs Wiring

The electrical circuit wiring is by planning which was created by the designer, and numbering the wires and put their tags, locations of Relays and connectors control are designed, which solve many tasks. When we want to change the system or add parts to it, should be Re-wiring or modification them.

2.1.3 Features of PLCs

The PLC facilitates many complex issues. Reduces wire density, facilitates the process of modification and redesign programmatically. The following are other advantages.

- The number of wires is lower than the conventional method.
- Performs operations quickly and easily.
- Includes functions diagnostics and processing
- Provide central diagnosis.
- Rapid documentation of applications
- The applications can be used repeatedly.

2.1.4 Construction of PLCs

CPU

The processor is the brain for the PLC, where the processor system consists of one or more microprocessor and a set of integrated circuits, types of integrated circuits vary according to their design and functions, including, logical functions, control functions and memory for the PLC system. The Logic is implemented according to the program applied and this is done periodically, during which it performs the calculations, to make the appropriate decision on the outputs. Figure 2.4 shows the operating cycle of the processor in the PLC.

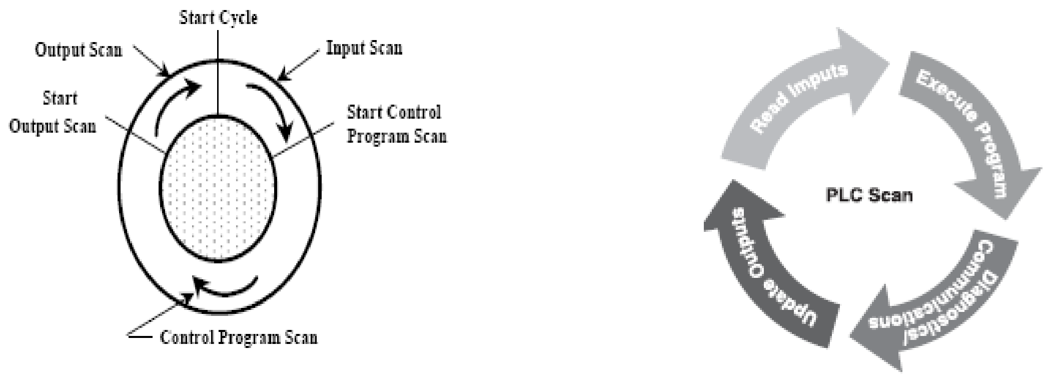

Figure 2.4: processor operating cycle [65].

When information is entered into the PLC via input modules, the processor uses it to make the appropriate decision according to the stored program such as counters, comparison, and sequence of operations, as in the figure 2.5.

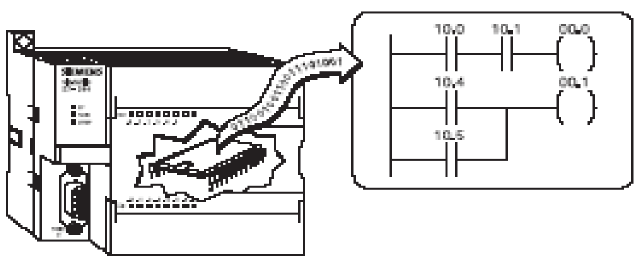

Figure 2.5: Programming process [65].

The external device signals are checked by the plc to see if they are present or not. During the programmed scan, that is, If the input devices are in an ON or OFF state. When data entered from the input module arrives it is saved in a temporary memory or a file in memory, as a table. The Processor uses it after examining the instructions in the program to make a decision on the output through it. The output status is also, written to the output table by doing, so the PLC affects external devices or remains without effect. The duration of this process takes from 1 to 25 milliseconds and is called the duty cycle.

Memory

The memory in the PLC is used for storing the program of the process to be controlled, usually in the same segment, as the processor. The information in memory determines the processing of the incoming and outgoing data. There are different memory sizes, the memory required is determined by the size of the project to be controlled

I/O System

An input / output system is a physical system that uses the transmission and reception of signals with a field. Deals with heat sensors, Pressure, level, flow and others. And they communicate in valve control processes, operating and extinguishing motors, alarm systems and others. The output models do not deal directly with devices consuming greater than 10 amperes, but affect the relay or conductor coil for operation or extinguishing, as shown in Figure 2.6.

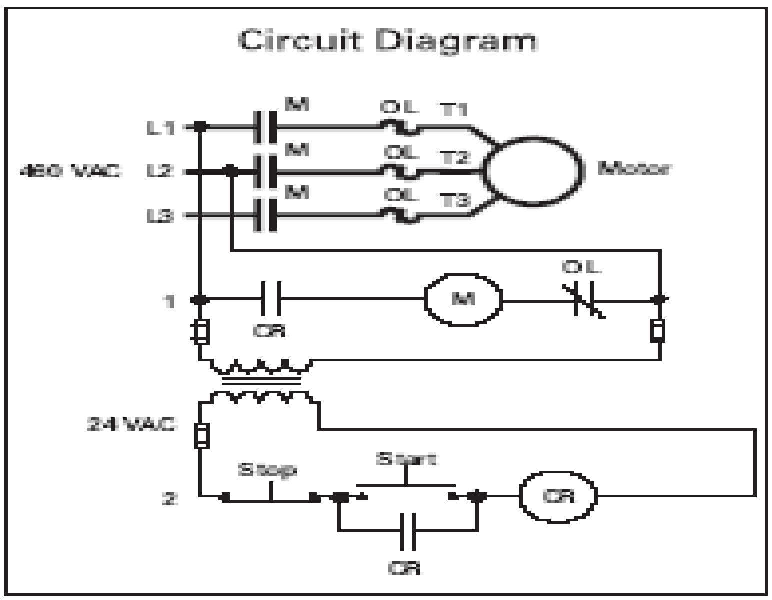

Figure 2.6: final control devices [65].

2.2 LITERATURE REVIEW

The previous studies have a positive impact on scientific research, it is the starting point for research. Most scientific research is directly related to the previous literature and sources, it is a market full of scientific subjects, which can be adopted by the researcher through the new information and data Naturally, The results are different because of different mechanisms and environments. In order to search for digital control systems that have become very important and play an important role in all methods of control in the industrial field, especially control of the speed of steam turbines whose speed control is strictly related to their outputs, and through the work of a number of researchers using different techniques to improve the controls in the speed of steam turbines and comparisons between the performance of the controllers of these techniques and the comparison between the performance of the controls that are tuned by various techniques, Had been reviewed many of the research that helped to reach the conclusions and theories and ideas of the other, it also, provided relevant information on the subject of the study and helped to make decisions on other parts of the study. A questionnaire was conducted to gather data, identify any aspects of which data may be needed, or any questions that could be used. A selection of these research has been selected for knowing the purpose, methods, techniques, contributions used and the knowledge of their conclusion.

E. L. Morris and B. Abaza (1976) [23]**.** The purpose of this research was to design an adaptive controller to control the velocity of the steam turbine. They used a linear least-squares method on the basis of online use. A small computer was used to collect data and achieve adaptive control off-line and online. The controller was designed to control under different load conditions. Due to the nonlinear effects of changes in the load on the system, it was partially chosen despite the availability to a large extent. With this algorithm, it was possible to use the fourth order samples and the sampling time of 0-5 seconds, Which is a low order or single length model, it was not changed. In this minimized model, the sampling time can be reduced by using floating-point-arithmetic package, although the turbine system is a high-grade system. The results showed that no significant benefit was obtained through consideration In a larger model of the second order gave better results, when it underwent a change in load.

Q. Zhu, Y. Zhang, and J. Zhang,(2008) [24]. To control the speed of marine steam turbines consisting of two cylinders high pressure and low pressure, the two cylinders were placed in parallel and connected through the pipes. It was possible be controlled according to the conventional method, The calculation could be done with the initial parameters and the amount of vapor flow, and in the form of stages, whose results are more accurate, but must be parameters is known in Each stage and more time-consuming. Due to lack of linearity, Uncertainty and complexity in the model steam turbines because of the complications of the marine steam turbine system, the conventional speed regulation system. No longer meets requirements. In the last years. The speed regulation system was used on the basis of combining the fuzzy and neural network. This sample is used to analyze the dynamics of propulsion of marine steam turbines.

P. Wang et al., (1999) [25]. For the purpose of controlling the turbo-generator speed controller system, They used the new hybrid algorithm DEPSO. Due to varying degrees of disadvantages of the individual algorithm, such as slow convergence speed and early convergence, thus, the hybrid algorithm (DEPSO) was proposed to overcome the defects of the individual algorithm based on the incorporation of particle swarm optimization(PSO) and differential evolution (DE), The algorithm was applied to determine non-linear parameters has a strong recognition ability and good condition adaptability, determine the parameters of the generator and to create the new optimal position of molecules, improve the trend of evolution and enhance the efficiency of research. Through the DEPSO algorithm's response to the simulation system it is an effective and useful system. The DEPSO algorithm is a new and effective method of parameter identification In the system of steam turbine regulation.

Yang Tao, et al., (2012) [26]. This study is concerned with the real needs of the system controlling the speed of steam turbines. There are many major issues such as practical testing for system speed control, data processing, parameter identification, The purpose is to test static, Variable and turbulent using various algorithms(genetic, fuzzy neural network and PSO) to develop control of the steam turbine using program one province in China It has been verified that the program integrates data processing, identification of fully functional parameters and confirmation of simulations, the program provides a variety of optimization algorithms and parameters in the linear and nonlinear parts. The program offers a variety of different analysis methods for the purpose of simulating verification. The software has a strong scalability and more applications, not only for parameter identification of steam turbine control system, but also for other control systems.

Fei Wang, et al., (2010) [27]. This study is looking at the system speed control and overload protection system. Record to the excess speed and dynamic stability, where it turned out to be problems Large steam turbines are treated in the design of an electronic over speed protection system, and to achieve control by Fuzzy self-tuning PID and its implementation on FPGA, The new technology achieved foggy self-adjust in control the PID on an FPGA (Field Programmable Gate Array) through incremental use PID algorithm and off-line lookup table method. The AD adapter is controlled by the FPGA-based controller. The computer communicate with the FPGA to make the connection reliable, in order to Perform a fuzzy PID control self-control by FPGA. They concluded The traditional PID controls that cannot be adjusted are not available at nonlinear speeds A self-tuning PID speed control technique, adjustment of PID parameters Real-time through experience. Summarize the control process, which is formed from the FPGA chip, The serial communication circuit, the signal processing circuit of the speed, pressure and power. The system design tweaks for online tests and after tests on the system show that the system works well.

S. Jovanovic,M(1999) [28]. This research is interested by improving the control type of the frequency for electric power through self-tuning to control the speed of the steam turbine, by applying the single adaptive controller for control. Using techniques (least-squares estimation technique and minimum-variance control technique) is to control high frequency and low frequency and protect the generator from disturbances. They concluded that control of the frequency change resulting from the change of speed in the generator may be reduced or avoided.

Patrick. Rock, Terry. Bauman, and Bill. Granzin, (2006) [29]. The purpose of this study is to comprehensively improve the process of controlling the steam turbines, used to produce electrical energy produced by steam pressure, because the cost of natural gas or wood used in steam production is less than the cost of electric power. Including control of the turbine, speed control by controlling the Steam pressure where the speed is constant in the case of pressure control, Turbine heating stages, Synchronization of generation to the transmission line(Bus) and control includes in the serial stages to start the turbine. They used the programmable control instead of the alternator, and they concluded the programmable logic controller (PLC) offers greater flexibility in turbine control and is also, more flexible, it has ready-made parts and controls that are easier to use and cheaper than others, ready-made functions, user-friendly interface. End the dependence on the OEM representative to reset the system down.

Lian Chen,(2010) [30]. The research dealt with a digital electric hydraulic system that controls on the speed of steam turbines to adjust their performance, which is difficult to conduct a precise mathematical controller. Due to the complexity of steam turbines that are affected by multiple external factors in the application Field, such as - change the temperature and change steam pressure. In this research paper used control of steam turbines using algorithm of Hybrid sensitiveness index optimization on $H\infty$, that can be improved using an improved sensitivity algorithm and they concluded, the error is less than 2.5mil, and the error is less, when the $H\infty$ robust control algorithm than the use of the PID control algorithm.

Mohamed. M. Ismail,(2012) [31]. This paper examines the self-control design process of the PID controller and specifically the isolated turbine speed control system in industrial enterprises. The isolated turbine system means that the turbine is not connected to the network. The PID designed on the basis of the fuzzy system and redesigned using the genetic algorithm and each of the PSO algorithms, ANFIS analyzed the results obtained from each of them. The system simulation was performed using a program designed by MATLAB simulink for tuning the PID controller. The input signal is a step and output turbine speed was represented by a curve. He concluded, the Adaptive Fuzzy designed PID is better than the other AI in terms of rising time, stability time and the BPSO designed better than the classic and designed by both GA and PSO in terms of response.

Sherin A. Kochummen, Dr. NE Jaffar, and Prof. Nasar Nasar(2015) [32]. This paper examines the speed control of steam turbines and used a method based on the Massachusetts Institute of Technology's(MIT rule)Adaptive Control Design (MRAC). They concluded that it Controlling the turbine speed is realized by coordinating the pressure control with steam, Improved accuracy, low steady state error and fast response.

Lu Guangxing et al., (2017) [33]. In this research, the data relied on the analysis of the generating turbine system, turbine speed control, synchronization of electric generation and governed by the model of different loads on the electric turbine and be a mathematical model. Used mathematical model of marine turbines system for simulation by MATLAB program which was used and inferred characteristic curves that resemble the value of actual curves under the influence of variable loads for the purpose of validating these results. Also, in this research. The work was done using visual C ++ program and applied the mathematical model in the program and the work encountered through which can communicate with the turbine, as shown in Figure 2.7. This program simulates the work of a real ship. The goal of this process is to train mariners and teach students in universities. They concludes that it can implement and save cost, certain application value.

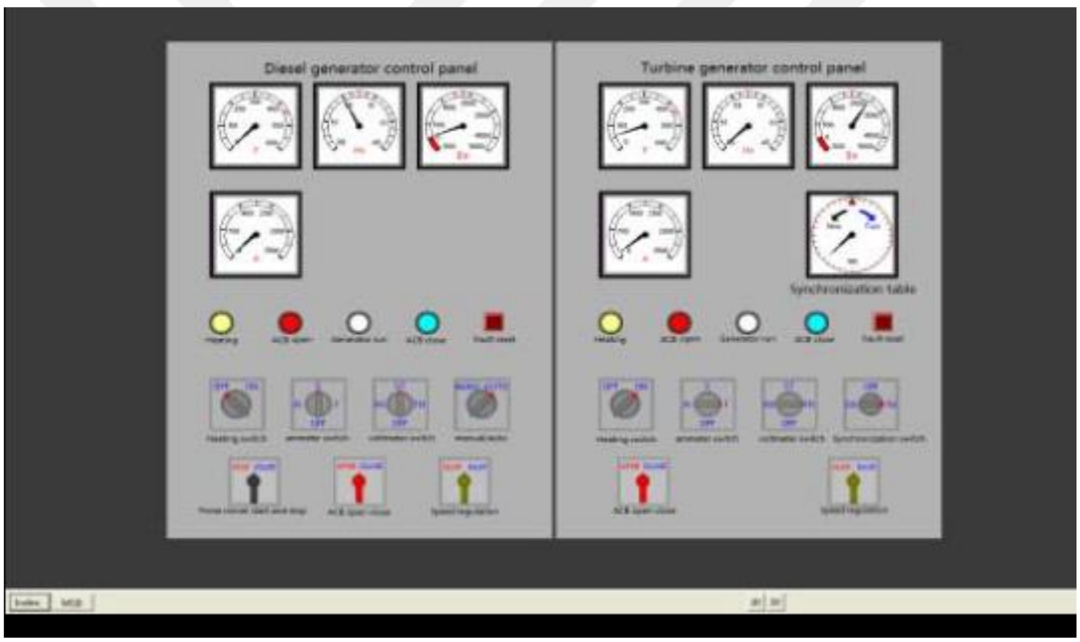

Figure 2.7: Interface of turbine generator screen [33].

WU Zhenlong, et al., (2016) [34]. The FOPID control module and the PID controller are introduced into the cascade control system. To control steam temperature roast, the external loop is controlled by the FOPID controller Or PID controller and by relative control Internal loop control The FOPID and PID control module is enhanced by the PSO algorithm according to Transfer Function equations in Eq.(2.1) and (2.2). The control is compared by different controllers The simulation results show that the closed loop system of the FOPID controller and the PID controller for the integer order, They have the same effect in tracking control while there are minor features of the previous ability to reject the disturbance, Durability. also, they concluded that the results of the FOPID controller are very close to that of the PID controller, because the variables μ and λ of the FOPID controller Very near to 1 as it appeared in the results.

$$G_1(S) = \frac{1.276}{(18.4S+1)^6} \quad (2.1)$$

$$G_2(S) = \frac{0.815}{(18S+1)^2} \quad (2.2)$$

Sanjoy Debbarma, Lalit Chandra Saikia, Nidul Sinha(2013) [35]. In this paper design dominated three areas of unequal thermal control systems, Different performance of the fractional order (FO) depending on the classic menu control such as FOI, FOPI and FOPID ,They are analyzed and compared with 2-DOF-FOPID ,Developed using the algorithm known as Firefly Algorithm (FA). It has been observed that the 2-DOF-FOPID controller gives much better performance than Control FO, It was found that the proposed control performance is also good when the system is subject to a higher degree of step load perturbation (SLP).

S. Debbarma, et al., (2014) [36]. In this research, the proposal of the PID controller (2-DOF-FOPID) to control the second degree of freedom to self-control the generator is studied. The proposed control unit was first tested on three thermal systems in different regions to test the heated generation turbine and the appropriate Generation Rate Constraints (GRCs), Used the Firefly (FA) algorithm to improve and test the performance of each 2-DOF-FOPID according to the control criteria. The convergence properties of FA were compared with a set of algorithms for knowing the difference between them, such as PSO, BFO and ABC algorithms. Optimization was used for several parameters simultaneously using FA, 2-DOF-FOPID controller performance was tested with random loading pattern and higher size than SLP and optimal durability of 2-DOF-FOPID coefficients was tested by sensitivity analysis, and they concluded that the DOF-FOPID is superior in terms of stability time and less disturbance as the superiority is enhanced by the PSO, BFO And ABC to confirm.

Mohamed Jasim Mohamed and M. Amjad Khashan (2014) [37]. There are two types of comparison in this paper. The first is the comparison of efficiency between different algorithms: GA and PSO. The second comparison is the efficiency of PID and FOPID controllers, that tuned by using GA and PSO algorithms. The controllers were applied to different types of systems: stable, non minimum phase, unstable. The difference between PID and FOPID controllers are number of parameter, FOPID controller need to improve a values of five parameters, and in the classical PID need to improve a value of three parameters. The integration and the derivatives process, used in FOPID are fractional and used in PID are integer. They concluded that the PID controller when used with GA and PSO algorithms gives the same results. The PSO algorithm takes as few generations or repetition as it takes less time than GA to find the ideal PID parameters. When using FOPID with optimal standards ITSE and ISE, gives better results than using PID for the same standards. That is, The FOPID controller gives better results than a conventional PID. They concluded the method of adjustment using PSO: easy implementation, ease of use to formulate the problem, the order of the procedures for its work remains unchanged with different problems where only a small part is changed, enables the designer to find optimal standards for the controller, as well as gives the designer from the use of different standards. This proposed method can be applied in all factories with their preferred results compared to other .

Ankush Kumar(2013) [38]. The control is expressed by a set of differential equations of FOPID. FOPID has been re-represented by a higher order by a second-class model with a time delay (SOTD) that has transfer function as show in equation (2.3). The fracture control system meets a range of frequency range, and when the fuzzy system appears that gives greater flexibility in the design of the controllers. Where the Fuzzy FOPID was developed depending on the effects of integral parts, and they concluded that Fuzzy FOPID is better than the traditional PID, FOPID and Fuzzy PID.

$$G(S) = \frac{0.6167}{S^2+0.2343S+0.2331} e^{-.866s} \tag{2.3}$$

M. Subramanyam, et al., (2012) [39]. This paper investigates how to propose a new method for control, to know if it can be used, and to improve control of steam turbine speed by PID. This is done by obtaining appropriate parameters for the controller. By using the control techniques that proposed by Y. Lee et. al. and Ziegler-Nicholas for comparison. The simulation was done using Labview. The new method that was proposed for tuning controller it was the internal control model (IMC). They concluded that using the IMC technology for PID tuning can enhance system control better by improving rise time, settling time, peak overshoot.

Amlan Basu, et al., (2016) [40]**.** This research deals with the design of PID and FOPID controllers, for heat a furnace where each is tuned by a techniques Ziegler-Nichols, Cohen Coon (CC), Chris-Hrons-Reswick (CHR) and Astrom-Hagglund (AMIGO), to find coefficients of differential, integration and proportional. The Nedlar Mead technique was also used to find FOPID adjustment parameters for the purpose of reducing response time and system instability. They concluded that when the controller is improved in any of these ways, a good response, and the Nadler Mead method when used, also gives a good response when used to tune FOPID, so it can be used.

$$G_I(S) = \frac{1}{73043S^2+4893S+0.93} \tag{2.4}$$

Rusdhianto Effendie, et al., (2018) [41]. In this research, they used the methods of controlling the spin speed of the multi-stage steam turbine, which it consists of low, medium and high pressure. The self-adaptive PID fuzzy, which controls the change in rotation speed, was used to compare its performance with set point and the RMSE value. A simulation program was done in MATLAB. They concluded that it was able to maintain the turbine rotation speed as set point 3000 rpm with load changes without overshoot at the beginning of operation, it is also good in terms of RMSE and varies slightly in all load changes.

Parvesh Kumar, Nitish Katal, and Shiv Narayan (2016) [42]. The researchers used this method to adjust FOPID by a multi-objective variant of flower pollination algorithm (MOFPA). For controlling on the speed of the steam turbine, The research mission is to improve system sensitivity and provide stability, from the results indicator. They concluded that the performance of the system is satisfactory, this method gives stability to the system and provides efficient control; therefore, the strong behavior of this system confirms the integrity of the control process and good results.

D. Mircea and B. Dorin ,(2014) [43]. The definition of the steam turbine and its work is presented in this paper. There are two categories of control of steam turbines. They said, operation control system and protection System, which protects the turbine from excessive speed and also turns off the turbine in case of emergency, depending on the valve, the process of controlling a valve may be mechanical, electrical, or digital that performs the functions programmatically. The Matlab software was used for simulation. They concluded that the output frequency is determined based on the speed control. That is the turbine is controlled, the turbine response is affected by the pressure of the steam enter into it. The system need additional controller it is enters to the work after the stability of the basic control of the speed of the system, steam turbines can provide good speed stability with the right speed controllers.

M. Farahani, S. Ganjefar, and M. Alizadeh (2012) [44]. This paper investigates the self-control of the frequency output of the generator, which is based on the control of the steam turbine speed. Its purpose is to suggest optimal PID by LCOA map-based chaotic algorithm (LCOA) to treatment the load-frequency control (LFC) issue. The Matlab software was used for simulation. After the results were obtained to adjust the PID by LCOA. It is used to examine the results of control in the simulation program. They concluded that the optimal PID is capable of solving the LFC problem as well as system performance in each field is convincing. A comparison was done between the performance of LCOAPID and the results obtained by the PIDs, which were tuned by other algorithms and showed that the LCOAPID results were better in each region as well as the efficiency of the improvement. This algorithm can also be implemented in a real time environment.

Shuangxin Wang, et al., (2011) [45]. This paper is concerned with lost time and saturation in the turbine control system, which are nonlinear characteristics and have been used as a method chaotic particle swarm optimization modified algorithm (CPSO) based on Skew Tent. Sine and others mappings they works well when used to improve multivariate functionality with large spaces. PID controller was used based on RBF neural network self-tuning, which can identify variables on line. They concluded in this way the control system can be very precise and has good dynamics, this strategy enables effective control of the complex object and creativity in the work and achieve practical application.

W. Y. W. Jingcheng (2011) [46]. This paper aims at finding high control performance in the speed of steam turbines and has been used control system, fuzzy PID controller for speed control. he had been used mathematical model (a differential evolution) for tuning the controller, and he concluded from the simulation program designed in the Matlab that this method has many advantages, including small overshoot, high durability and rapid response compared to the traditional PID control.

Y. Ren, et al., (2010) [47]. In this research model, the neural network of radial basis functions is used with self-regulation and rapid convergence in the modeling of speed control system of steam turbines. Used technology combines both the particle swarm optimization algorithm and the lower squares algorithm for neural network training. They concluded that it is characterized by high precision and quick convergence, after training, this proposed model and training algorithm are used for a power plant, and through the results show that the neural network can be used in modeling the speed control system for energy system stability studies.

Rekha Rajan, S. P. Muhammed, and N. Anilkumar,(2013) [48]. In this paper, the process of controlling on the steam turbine and defining it as a device that converts thermal energy from compressed steam and converts it into mechanical energy in the form of a rotating shaft, can take advantage of the rotational motion in the rotation of generators, and demonstrate the importance of controlling the rotation speed and consider it necessary. Turbine operation has been said to require speed stability to be maintained for electricity generation. When the speed of rotation exceeds the set limit, the steam control valve reduces the flow inlet, if this fails, the turbine may continue accelerating until its parts are damaged. The effectiveness of the different control units for controlling the speed of single reheat steam turbine was investigated. The MPC (model predictive control) was proposed to control the steam turbine speed mentioned. Then compare the results with the performance results of the console with conventional PID and fuzzy PID controllers, which were presented in the search. Process simulations were used by matlab. They concluded that the MPC controller could improve robustness , small overshoot and fast response compared to the conventional PID and fuzzy PID. The speed control response is better for steam turbine speed control.

2.2.2 Summarize Previous Research

By reviewing previous studies that include different methods to improve the controllers and the process of controlling the steam turbine speed with different types of controllers and various methods of tuning the controllers, each of these techniques has its method and its potential to improve the control process, where there were varying degrees between the performance of the controllers in terms of response Of changes and turbulence in the control process. The technique used to adjust the parameters of the controller has a great effect in improving the controller work. There is research that combined two techniques to improve the controller as in [3,6] which gave good results. Research has used new methods to improve the system for the purpose of knowing its performance compared to known algorithms as it in [5] and has achieved better results than the traditional method. Other studies have used programs to simulate control. The steam turbine speed control process has extensive studies, but there has been little interest in comparing the performance of the FOPID controller with the PID controller when their parameters are adjusted by the genetic algorithm. Therefore, our thesis focused on choosing this aspect to achieve better automatic-control among them.

3. THIRD CHAPTER

3.1 GENETIC ALGORITHM

3.1.1 Introduction

Algorithms are used in different fields and not only in the industrial field, for example the fuzzy algorithm was used in developing the evaluation of university standards, it turned out to be important and could substitute for classic models. In this thesis the genetic algorithm is used in the process of improving parameters. The GA.s algorithm is one of the universal methods of random research that simulates evolution. They are also ways of improving. It was officially introduced in 1970 by John Holland in the United States at the University of Michigan. Because of its continuous improvement of system types and computations, they have made it attractive among optimization systems [49,50]. The genetic algorithm, which does not have the first facts, begins with the correct solution to search for the best way to reach the best results based on environmental and evolution factors such as reproduction and mutation. Parallel methods are adopted to reach the solution and avoid convergence in solutions [51,67].

3.1.2 Characteristics of Genetic Algorithm

The genetic algorithm in the process of research and optimization of computational performance is based on two biological principles: natural genetics and natural selection Genetic algorithm. They does not provide only one possible solution to the problem, but a set of possible solutions. This is the concept of a potential solution population named chromosomes. The Chromosomes are coded expressions of solution parameters. A comparison is done. Between each chromosome of the other chromosome of the population, they are given a fitness rating and determines the level of success of the chromosome in the last chromosome. The genetic algorithm is used to encode solutions of the best genetic factors, such as mutation and crossover For using existing chromosomes in the population to create new chromosomes [52]. This is done either by modifying existing chromosomes or by integrating assets into the population. Parent chromosomes the fitness are taken into account in the choice of mechanism. In order to ensure a greater chance of a better solution of the mother chromosomes to donate their beneficial traits to their progeny. Genetic algorithm configuration typically, it consists of members for a random population, numbering between 20-100 member. The representation of a mating pool or population is done by a number of real value or a binary string called a chromosome.

For clarification purpose, each chromosome is represented as a binary string in the rest of this chapter. An individual's task performance is measured by the goal function. The goal function assigns each individual a matching number named fitness. Each chromosome is evaluating his fitness and applying the fittest stay. In this thesis the fitness of each chromosome will be set using the amount of error. The three main stages of the genetic algorithm are named reproduction, intersection and mutation. It will be detailed later [53].

3.1.3 Reproduction

The fitness value of each chromosome is assessed during the reproductive phase. This value is used to choose the bias towards experienced individuals. As in the natural evolution process. The appropriate chromosome is more likely to be selected for reproduction. The selection of a ‘Roulette Wheel’ is an example of a common selection method, as shown in Figure 3.1. Each member of the population is allocated his roulette wheel. The size of the section is proportional to the fitness of the individual. The individual is selected by the axis indicator to which it refers. This process continues until the selection criterion is met. The probability of choosing people is related to fitness and this makes the possibility of leaving offspring to the experienced individuals. Multiple copies of the same series may be selected, but the series of experienced individuals is dominant. Therefore, for example in Figure 3.1, the weakest chain (01001) cannot control the selection process. There are four common uses purpose of selection.

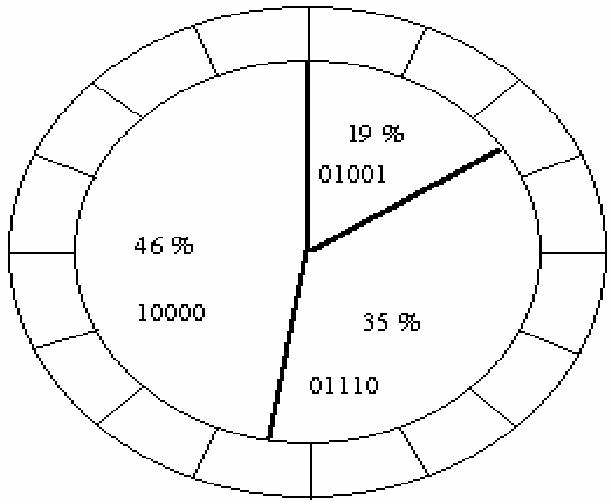

Figure 3.1: characterization of RWS [53].

It is up to the user to choose the appropriate method for each operation from the available methods. The basic principle is supported in all selection methods, for giving the mechanical chromosomes greater choice [53].

There are four main uses for the selecting.

- First method is Roulette Wheel selection(RWS)
- Second method is Stochastic Universal sampling(SUS).
- Third method is normalized geometric selection.
- Forth method is tournament selection

3.1.4 Crossover

After you complete the crossover algorithm selection process, you are started. Certain parts are exchanged in crossover action and exchanged between two selected chains in an attempt to obtain good parts of older chromosomes for the purpose of creating a new one with better genetic traits. Chromosomal properties are processed directly using genetic operators. The genetic codes of individuals are confirmed using that hypothesis. in the middle. For the production of experienced individuals. The probability of a transition indicates how most of the transition is performed. If the probability is 0%, it means that the older generation will transfer the same genetic conditions to the offspring. If the probability is 100%, there will be a generation with new characteristics of the offspring. Crossover of Single Point is the simplest crossover technique and consists of two stages:

1. Individuals of strings that Newly produced are mated randomly in the mating pool
2. The intersection is done on each pair of strings as follows: where a random integer K is chosen between the length of the string less than one and the one, [L- 1,1]. replacement all characters between the location of k + 1 and L for creating two new series.

Example: Selecting string values 10000 and 01110, as an example, after which we select crossover and then choose a value of 3 random value of k will produce new strings 10010 and 01100 as in Figure 3.2.

Figure 3.2: Crossover as Single Point [53].

Other models of crossover techniques are more complex than the previous model. Such as multi-point crossover technique and Uniform technique. Multi-point crossover is an extension of the previous single-point crossover technique. This technique has principle is to work on the parts of the chromosome that it is contribute more fitness that it Probability to not be adjacent. It also consists of three strategies.

1. Mating is random for Individuals of the newly produced strings in the mating pool.
2. The ascending order of a randomly selected location is done without repeating.
3. For producing new offspring, bits are exchanged between consecutive crossover points

Example: When we select the 11111 and 00000 series to cross, and set the multipoint intersection locations to be 2 and 4, a new generation of strings will produce 11001 and 00110, as in the Figure 3.3.

Figure 3.3: Crossover with Multi-Point [53].

Uniform crossover a series of once and zeros is used as a random mask where it has the same for the original strings for performing the following:

1. Mating is random, for Individuals of the newly produced strings in the mating pool.
2. Each string is masked when the mask bit is zero. The corresponding bit of the other string is placed in it a position. If it is one, it will retain the basic bit [53,66].

Example: When we select the 10101 and 01010 series to crossover with the mask 10101, we'll get a new series. 11111 and 00000 as in Figure 3.4.

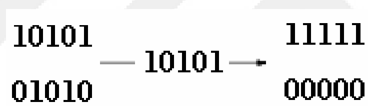

Figure 3.4: Crossover as a uniform [53].

3.1.5 Mutation

Through the previous two steps: Selection and Crossover will generate many new chains, but there are two problems that will be faced:

1. The initial selection of the population shows that it is likely that GA research in the problem area will not be confirmed due to insufficient initial strings.

2. GA may choose chains that are not efficient because of the poor choice of the initial population.

These problems can be overcome through the use of the mutation operator within, the mutation is defined as an accidental random change of the location value of the chain. The background operator in the genetic algorithm considered that a mutation within the genetic algorithm has a low probability, because the high rate of mutation can destroy appropriate sequences and make the genetic algorithm with random search. The probability of a mutation in the genetic algorithm is about 0.1% or 0.01% common. These percentages represent the selection of a particular sequence of the mutation. One string is selected for change by randomly changing an element in the string or mutation. We can represent this by choosing GA for the fourth bit to create a mutation in the binary string 10000, which will result in a string like 10010 that flips the fourth bit in the string, as in the figure 3.5 [53].

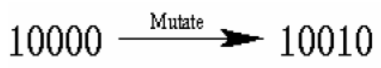

Figure 3.5: Operation of Mutation [53].

3.1.6 Genetic Algorithm Schedule

The flowchart below is summarized the genetic algorithm, a brief description of the process follows.

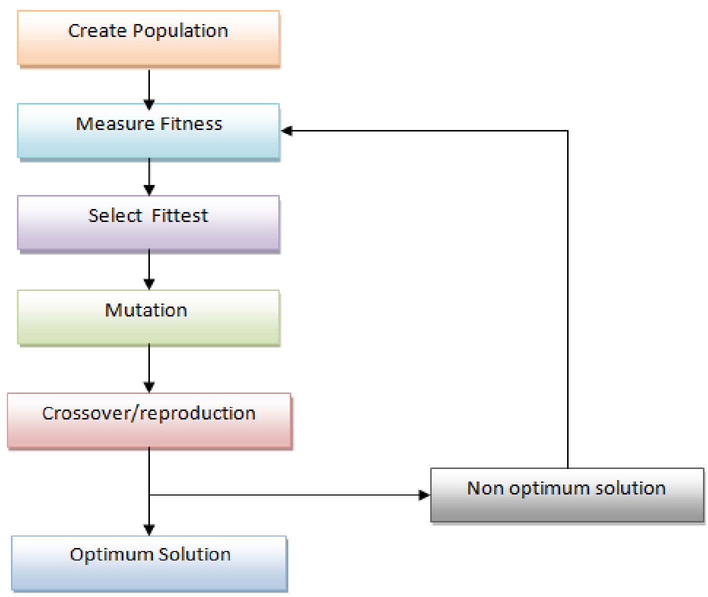

Figure 3.6: The Genetic Algorithm schedule [53].

The steps below are performed for creating the genetic algorithm.

1. Create first individuals randomly and at a fixed size.
2. Evaluate the fitness of the first Individuals that was generated.
3. Taking the fittest individuals of the population.
4. Using the probability method for reproduction is an example (roulette wheel)
5. Use the crossover process for implementing them on the chromosomes reproduce.

6. Use the low probability with implementation of the mutation operation.
7. Step 2 is repeated until the desired convergence criterion is obtained.

In the genetic algorithm the convergence criterion is a user-defined condition, such as the maximum number of generations or after completing a fitness string a certain value [54].

3.1.7 Elitism

There is no guarantee that the most appropriate chain is maintained by operators with crossover and mutation. This is a significant risk that the best solution may be lost, to solution this situation, an Elite model is used, where by the value of the best individual in the population is preserved at the beginning of the process and before any action, And after implementation and obtaining a new generation of the population and assessing the individual is compared the efficiency of the individual saved with the new generation, if it better than them, if it is not, introduced into the population. The genetic algorithm continues on as normal [55].

3.1.8 Objective Function

When creating the genetic algorithm, the objective function is the most difficult part of writing, And has been used in this thesis to evaluate the better Fractional Order PID and integer order PID controllers for controlling on speed of steam turbine system that has repeater. The purpose of the objective function used with PID and FOPID controllers is to obtain the fastest rise time, The fastest settling time and the smallest overshoot[56], so the objective function design is to combine all this objectives and reduce the error in the control system. The chromosome in the population is passing once to the target function, after the chromosome is passed is evaluated and assigned a number to represent its fitness. The chromosome that has a larger fitness number is better. Fitness values are then used by the genetic algorithm to create a new population of the best members [57].

If the algorithm is used to adjust PID and FOPID, each one chromosome consisting of three individual chains to form P, I, D, and five individual chains if used with FOPID, as specified when creating a population. In the case of PID the chromosome is divided into three separators upon entering the evaluation function, five breaks are in the FOPID state. For creating the PID, the gains P, I and d are used and p, i, d, λ and μ to create FOPID according to the equations.

PID $$G_{PID} = \frac{K_d s^2 + K_p\, s + K_i}{s} \qquad (3.1)$$

FOPID $$G_c(s) = K_p + \frac{K_i}{s^{\lambda}} + K_d s^{\mu} \qquad (3.2)$$

A feedback loop is formed with the steam turbine transfer function and the newly formed PID and FOPID controllers. In order to reduce the compilation time of the program, the transfer function is defined in another file and imported as a global variable. The error for the controlled system is evaluated using an appropriate MSE after a step input is given. Depending on the size of the error, the overall fitness value of the chromosome is set fitness increases with less error.

3.2 PID CONTROLLER

3.2.1 Introduction

A PID is an algorithm that includes three separate static parameters, which can be called a three-process controller, additional proportional parameter by P, and the integration process for the signal of sin is symbolized by I, the derivation of the error signal is denoted by D. According to the temporal concept, these values are classified as: P depends on the current error, I on the accumulation of past errors and D is a prediction of future errors, based on the amount of change the combined controller of the three cases is used to address the change and influence the valve position or any part is done Control it. The PID is commonly used in close loop system control. Multiple forms can be obtained by the PID controller, which can be used as an independent controller or a major part of a control system such as DDC, DCS and PLC. It is a control system at different levels commonly used in factory procedures such as companies Production of power or oil refining companies note that the modern control units used today are the PID controllers [58].

Among the controllers, PID is the most useful control tool, which provides a control procedure by adjusting the three parameters to control a specific operation. The quality of the controller performance depends on the process in terms of speed of response to faulty operations.

In some applications, it does not require the use of all PID actions, but one or two actions are sufficient and achieve proper system control. In this case, the parameters of the other actions are zero. For example, if the integral and proportionality are used, the controller designation is PI, in the case of the use of proportionality and derivative PD, and in the case of integration only I, as shown in Figure 3.7. Also, when integration is not used, access to the control objective is unlikely.

Entry in Type menu	Controller Type	Continuous-time Controller Formula (parallel form)	Discrete-time Controller Formula (parallel form, Forward Euler integrator formulas)
P	Proportional only	K_P	K_P
I	Integral only	$\frac{K_i}{s}$	$K_i \frac{T_s}{z-1}$
PI	Proportional and Integral	$K_p + \frac{K_i}{s}$	$K_p + K_i \frac{T_s}{z-1}$
PD	Proportional and Derivative	$K_p + K_d s$	$K_p + K_d \frac{z-1}{T_s}$
PDF	Proportional and Derivative with first-order filter on derivative term	$K_p + \frac{K_d s}{T_f s + 1}$	$K_p + K_d \frac{1}{T_f + \frac{T_s}{z-1}}$
PID	Proportional, Integral and Derivative	$K_p + \frac{K_i}{s} + K_d s$	$K_p + K_i \frac{T_s}{z-1} + K_d \frac{z-1}{T_s}$
PIDF	Proportional, Integral and Derivative with first-order filter on derivative term	$K_p + \frac{K_i}{s} + \frac{K_d s}{T_f s + 1}$	$K_p + K_i \frac{T_s}{z-1} + K_d \frac{1}{T_f + \frac{T_s}{z-1}}$

Figure 3.7: Controllers Type [58].

3.2.2 PID Controller Theory

After the implementation of the three actions of the PID, The purpose of correcting the on error signal is to call the signal coming out as Manipulated Variable (MV). It is obtained from the actions used on the input: proportionality, integration and derivative. The result of which is the output of the PID controller, known as $u(t)$. The designers of the PID control process classify the structure of these three processes into three different classes. They are called interactive, non-interactive, and parallel. PID controller manufacturers can use different algorithms that are programmatically expressed, which represent the PID-based structure.

3.2.2.1 Interactive algorithm

$$u(t) = K_c \left[e(t) + \frac{1}{Ti}\int_0^t e(t)dt \right] \times \left[1 + T_d \frac{d}{dt} e(t)\right] \tag{3.3}$$

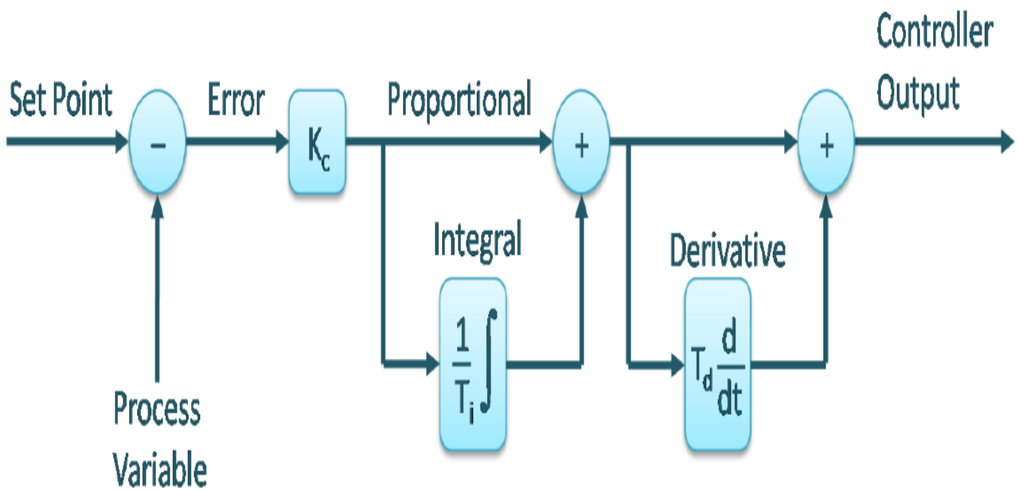

Figure 3.8: Interactive Algorithm [60].

3.2.2.2 Non interactive algorithm

$$u(t) = K_C[e(t) + \frac{1}{Ti}\int_0^t e(t)dt + T_d \frac{d}{dt} e(t)] \tag{3.4}$$

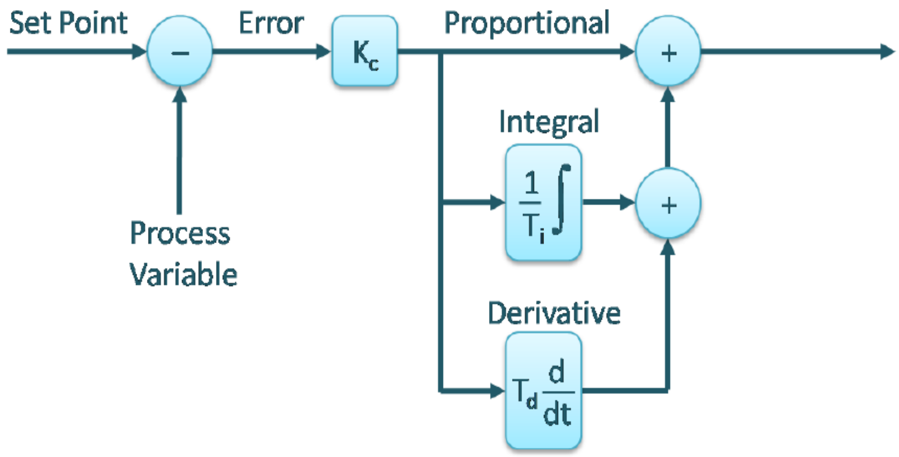

Figure 3.9: Non inter active Algorithm [60].

3.2.2.3 Parallel algorithm

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t) \quad (3.5)$$

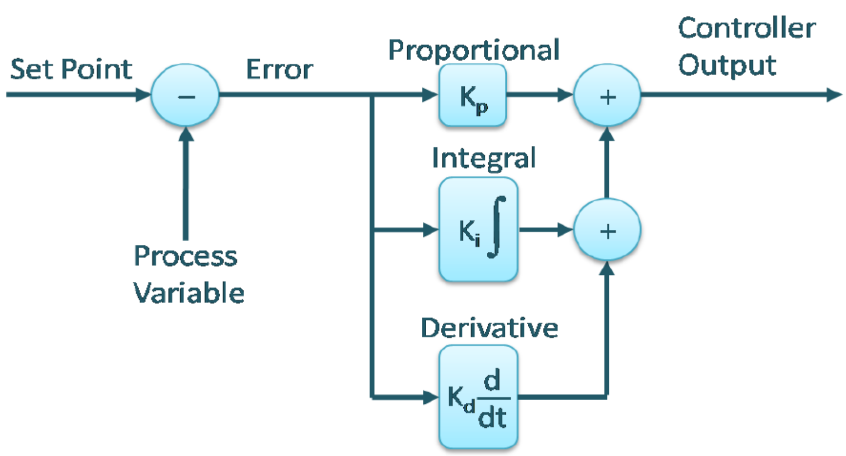

Figure 3.10: Parallel Algorithm [60].

Where

kp=Kc: Proportional Gain

ki=$KcTi$: Integral Gain

kd=$KcTd$:Derivative Gain

$$Gain\ e(t) = r(t) - y(t) \tag{3.6}$$

Proportional Term

Errors are multiplied by a value proportional to the error value called the proportional term K_P for the purpose of controlling the response. This part represents the relative gain obtained by the equation (3.7).

$$P = K_P * \ Error \tag{3.7}$$

proportional gain can be highly effective in changing the system output error. The very large proportional gain causes the control system to become unstable. Conversely, if the proportional gain is small and the error is large, the system sensitivity will be reduced or less responsive. If the gain is very small compared to the input error, the response procedure is very small for the system disturbances, the proportional gain function in the system tuning theories is shown to be the biggest cause of change in output, as shown the figure 3.10.

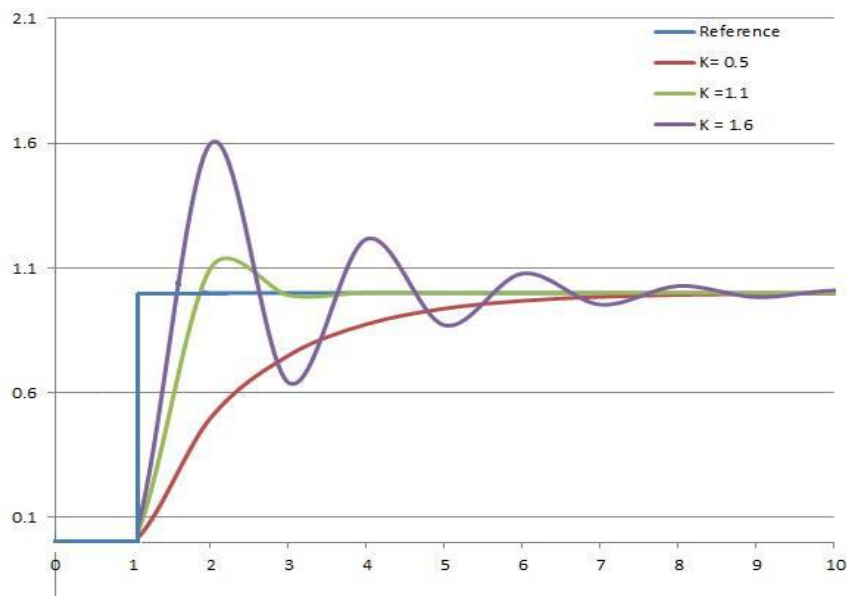

Figure 3.11: Effective of proportional parameter values [60].

Integral Term

The integration process in the PID controller contributes to the error correction and depends on the duration of the error and the error value. The integration process in which instant errors are collected over time and gives the accumulated compensation that needs to be corrected previously. The integration gain of K_i is multiplied by the value of the accumulated errors and then combined with the output of the controller.

$$I = K_i * \int_0^t e(t)dt \tag{3.8}$$

The integrated term removes the error of the stable state that occurs with the pure proportional controller and accelerates the correction response time to the set point. The value generated by the integration process may exceed the set point value due to the response to the accumulated errors of the past.

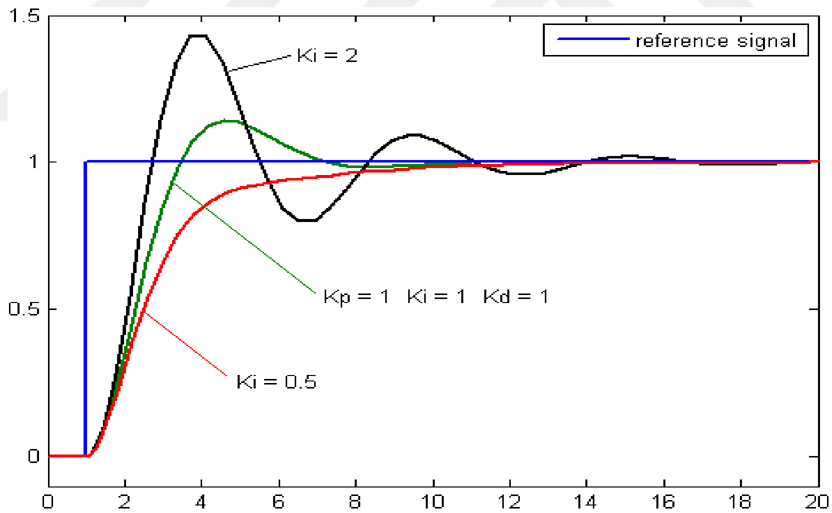

Figure 3.12: Effective of $\boldsymbol{K_i}$ parameter values [60].

Derivative Term

The derivative action within the PID configuration that which by the error inclination of input is determined over time and multiplied by the rate of change resulting by the derivative gain $\mathrm{K_d}$. Is obtained by the following expression.

$$\mathrm{D} = \mathrm{K_d} \frac{\mathrm{d}}{\mathrm{dt}} \mathrm{e(t)} \tag{3.9}$$

The derivative system has a distinct effect on the PID controller, it has the property to predict the behavior of the system and thus improves the stability time and stability, PID is able to add a further low nomination to the term derivative to reduce noise and high gain. The derivative procedure is of little use in practice because of its effect on changing the stability of the system in the applications practical [57].

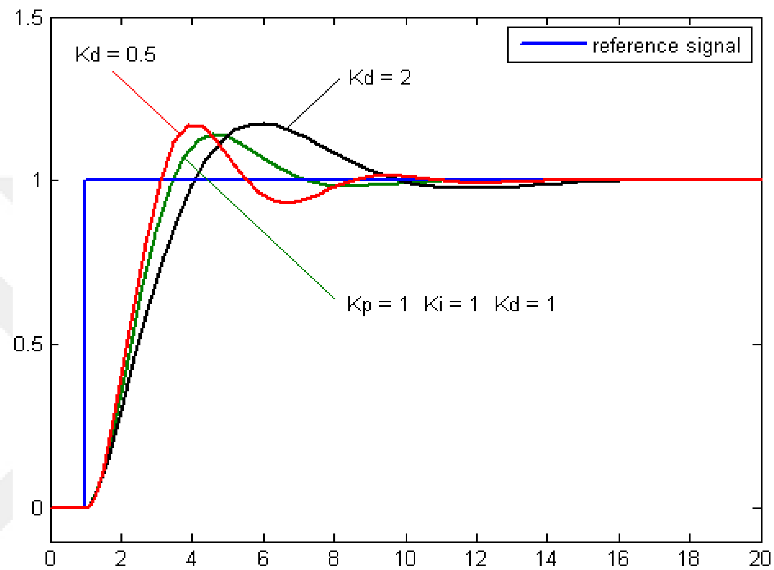

Figure 3.13: Effective of K_d parameter values [60].

Table 3.1: The effect of PID parameters on the response [60].

Parameter	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
K_p	Decrease	Increase	Small Change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor Change	Decrease	Decrease	No Effect	Improve if Kd small

The annular PID parameters are adjusted by several methods. The tuning techniques provide the most suitable parameters for the operation and are very effective compared to the manual tuning which is less effective. By adjusting the selection of P, I and D depending on the dynamic model. The choice of how to set the PID parameters depends on the response time of the system when it is offline. The output time of the system is measured when a step is entered in the offline state for knowing the response speed of the change, and use this response to specify control parameters. In this thesis, the genetic algorithm is used to adjust the PID parameters.

3.2.3 Continuous PID

When uses the controllers P,I &D together, will be represented by the equation (3.9) [59,68]. The block diagram Figure 3.14 for clarification.

$$G_c(s) = K_p\left(1+\frac{1}{T_i\, s}+T_d s\right) \tag{3.10}$$

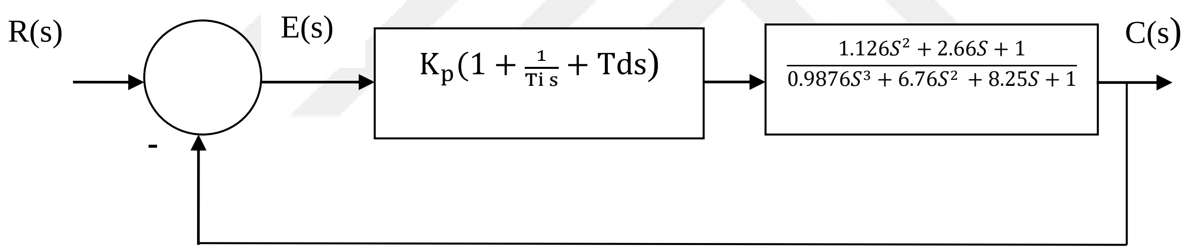

Figure 3.14: Continuous PID Controller [59]**.**

3.3 FRACTIONAL ORDER CONTROLLER (FOPID)

3.3.1 Introduction

Control operations in industrial facilities require distinct performance techniques, meet the needs of the system as best as possible and satisfy operators. In most industrial applications, The controller the integer order have been used in the control system for a long time, A new modeling was used for improving the performance of controlled operations by using the fractional order controller, which became highly dependent, abbreviated P ^ λ D ^ μ. One of the features that make the fractional controller characterized by its performance is that it has more freedom to improve the gain parameters that exceed the normal parameters ($K_P,\ K_i, K_d$) with two additional parameters (λ, μ), that enable the integration and derivative process to use the real numbers within the control process, thus using five variables, as appeared in Figure 3.14, the Fraction Order PID controller disseminates the PID control to regular whole numbers and extends them from point to point. This development can give a lot more noteworthy adaptability in PID control plan. The exchange capacity of such a controller has the accompanying structure $PI^{\lambda}D^{\mu}$ [62,61].

$$G_C(s) = k_p + \frac{k_i}{s^{\lambda}} + k_d s^{\mu} \quad (\lambda, \mu > 0) \tag{3.11}$$

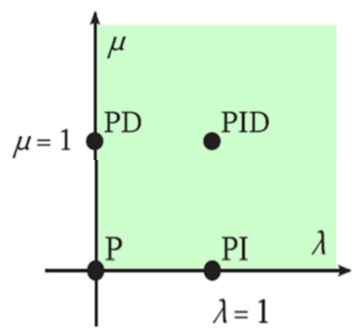

Figure 3.15: Fractional order PID (FOPID) general form [62].

This form, by selected $\lambda = 1$, $\mu = 1$, PID controllers classical can be recovered. By Use ($\lambda = 1$, $\mu = 0$) & ($\lambda = 0$, $\mu = 1$), respectively correspond to the traditional PI & PD controllers. All types of classical PID controllers are special status of the $PI^{\lambda}D^{\mu}$controller [69].

3.3.2 The Characteristics of Fractional System Control

Gives a partial request that the accompanying preferences when contrasted with the whole number request .

• The control unit in the partial request is less touchy than the exemplary PID controller, if the control parameter of the framework changed.

• FOC and two extra tune factors. This gives Additional grades of opportunity to the dynamic properties of the partial request framework

3.3.3 Fractional order PID tuning

The PID design is used by the integer numbers and the fractional numbers in the case of fractional numbers are setting according to the following domain [63]:

1. **Frequency**.
2. **Time**.

A. Frequency field Analysis

"Monje -Vinagre" proposed an enhancement strategy fractional controller setting for tuning the Fraction Order PID controller [63]. In this technique, a suggest tuning rule depends on a predefined attractive conduct of the controlled framework identified with determined estimation of the value for the following objectives.

1. No unfaltering state blunder
2. Specified addition hybrid recurrence

$$|C(jW_{cg})|_{dB} = 0dB \tag{3.12}$$

3. Specified stage edge $\emptyset_m$spoke to

$$-\pi + \emptyset_m = \arg\left(C(jw_{cg})G(jw_{cg})\right) \tag{3.13}$$

4. Robustness against varieties of additions of the plant, so around the increase traverse recurrence period of the open circle exchange work must be consistent.

$$\left(\frac{C(jw_{cg})G(jw_{cg})}{dw}\right)_{W=Wcg} = 0 \tag{3.14}$$

5. For dismissing high-recurrence commotion, at high frequencies the shut circle exchange work must have little size. Accordingly it is required that at some predetermined recurrence its extent be not exactly some predefined gain.

$$|T(jw) = \frac{C(jw)G(jw)}{1+C(jw)G(jw)}|_{dB} \leq AdB \; at \; frequency \; w \geq w_t \text{ rad /s} \tag{3.15}$$

6. The affectability work must have a little size at low frequencies.

$$|\,S(jw) = \frac{1}{1+c(jw)G(jw)}\,|_{dB} \;\le\; B\ dB\ at\ frequency\ W \le W_s\ \ rad/s \qquad (3.16)$$

These steps are all used by the closed system for adjusting the five FOPID parameters. The above nonlinear equations are used simultaneously to find the five coefficients of FOPID.

B. Time domain Analysis

The optimal time setting for the FOPID controller is concerned with selecting the best parameters for the controller in the higher order Process and reducing the integrated performance of the time range. Performance is evaluated by means of the original process model without lowering the actual model process higher order, but the physical laws governing the process must be well known, and the unstable conditions of the closed-loop system in search should be also restricted. Console parameters ($K_P,\ K_i, K_d, \lambda, \mu$) were searched while reducing the performance index of time domain, the process of optimization is not guaranteed in the stability of the closed-loop system, Delays the response of the lower order to the higher order, because it is controlled by two complex and interconnected poles. There are several rule for designing controller when we use it in time domain that will give different results:

1. $ISE\ = \int_0^t e^2\,(t)dt$ (3.17)
2. $IAE\ = \int_0^t |e(t)\,|dt$ (3.18)
3. $ITSE\ = \int_0^t e^2\ t\ dt$ (3.19)
4. $ITAE\ = \int_0^t t|\ e(t)\,|dt$ (3.20)

3.4 THE NINTEGER TOOLBOX

Ninteger is a toolbox is a box provided by Matlab through which you can get a lot of features that help to execute the commands of the controller fractional order, and can be used by the designer for implementing control operations by Matlab, it can be located in the program or download from the Internet, it executes Fractional order controllers in frequency domain and time domain. There are many methods supported by this fund can be used in the implementation of the approximation of the fractional order as up to thirty methods as well as three methods of identification. This box enables us to implement, analyze and simulate the control unit in a fractional order through its functions. There is a nipid function in this box where you can execute the simulation and execute the commands of the controller. The simulation process is via the simulation window in the Nintblocks which also equips a library. There is a PID controller inside the library through which the controller is executed in the FOPID order which can also be implemented from the PID in function.

- The gain with proportional
- The gain with derivative
- The fractional derivative order Process
- The gain with integral
- The fractional integral order Process
- The bandwidth of frequency domain approximation Process
- Poles number and zeroes number of the approximating
- The approximating formula Process

The use of the fractional order controller is very important in practice with the bandwidth and approximation of its limited dimensions. The fractional order controller has practical benefit, but should be within appropriate frequency. The reason is that when used as a simulation system, it has a large memory, but in the true process is limited memory.

3.5 SIMULATION

In this study, the parameters of the PID and FOPID controllers are adjusted when used for steam turbine speed control, based on the genetic algorithm to obtain the best results each can provide, and the results are analyzed through the table of response time and diagrams obtained from the simulation program applied. The Matlab and the steps are as follows:

- Analysis of the mathematical behavior of the speed the Steam Turbine through a mathematical equation (3.21).

$$GT(s) = \frac{1.126S^2+2.66S+1}{0.9876S^3+6.76S^2+8.25S+1} \tag{3.21}$$

- Know the mathematical configuration of the PID and FOPID controllers, and mathematical factors that affect the improvement of their work.

- Applying the technique of genetic algorithms and employing them to select the best results that affect the improvement of PID and FOPID factors as in the Figure 3.16, applying both of them to the speed of the steam turbine control unit.

Use the previous steps programmatically in MATLAB for simulating the control process, obtaining results for each of them, analyze the results given by each of them through drawing and find out who achieves better control [64].

3.5.1 Genetic Algorithm Appling

The steps below are performed for creating the genetic algorithm and the figure 3.16 For clarification.

1. Create first individuals randomly and at a fixed size.

$$x_1, x_2, x_{3,} x_4, \dots \dots x_n$$

2. Evaluate the fitness of the first Individuals that was generated.

$$Z(i) = \sum(\sum(xx(:,:,i) * C)) \tag{3.22}$$

3. Taking the fittest individuals of the population.
4. Using the probability method for reproduction is an example (roulette wheel).

$$P_i = \frac{F_i}{\sum_{j=1}^{n} F_j}, i = 1,2,3 \dots \dots n \tag{3.23}$$

$P_s(x)$: Probability of electing an individual x.
$f(x)$: Efficiency value for individual x.

5. Use the crossover process for implementing them on the chromosomes reproduce.

$$\text{offspring } 1 = a * parent\ 1 + (1 - a) * parent\ 2 \quad (3.23)$$
$$\text{offspring } 2 = (1 - a) * parent\ 1 + a * parent\ 2 \quad (3.24)$$

6. Use the low probability with implementation of the mutation operation.

$$q = \frac{pr}{2} \quad (3.25)$$

7. Step 2 is repeated until the desired convergence criterion is obtained.

3.5.2 Matlab

A Matlab program is used for simulating the FOPID controller as attached in Appendix A.1 and another program that simulates the work of the PID controller as in Appendix A.2, as shown in figure 3.17.

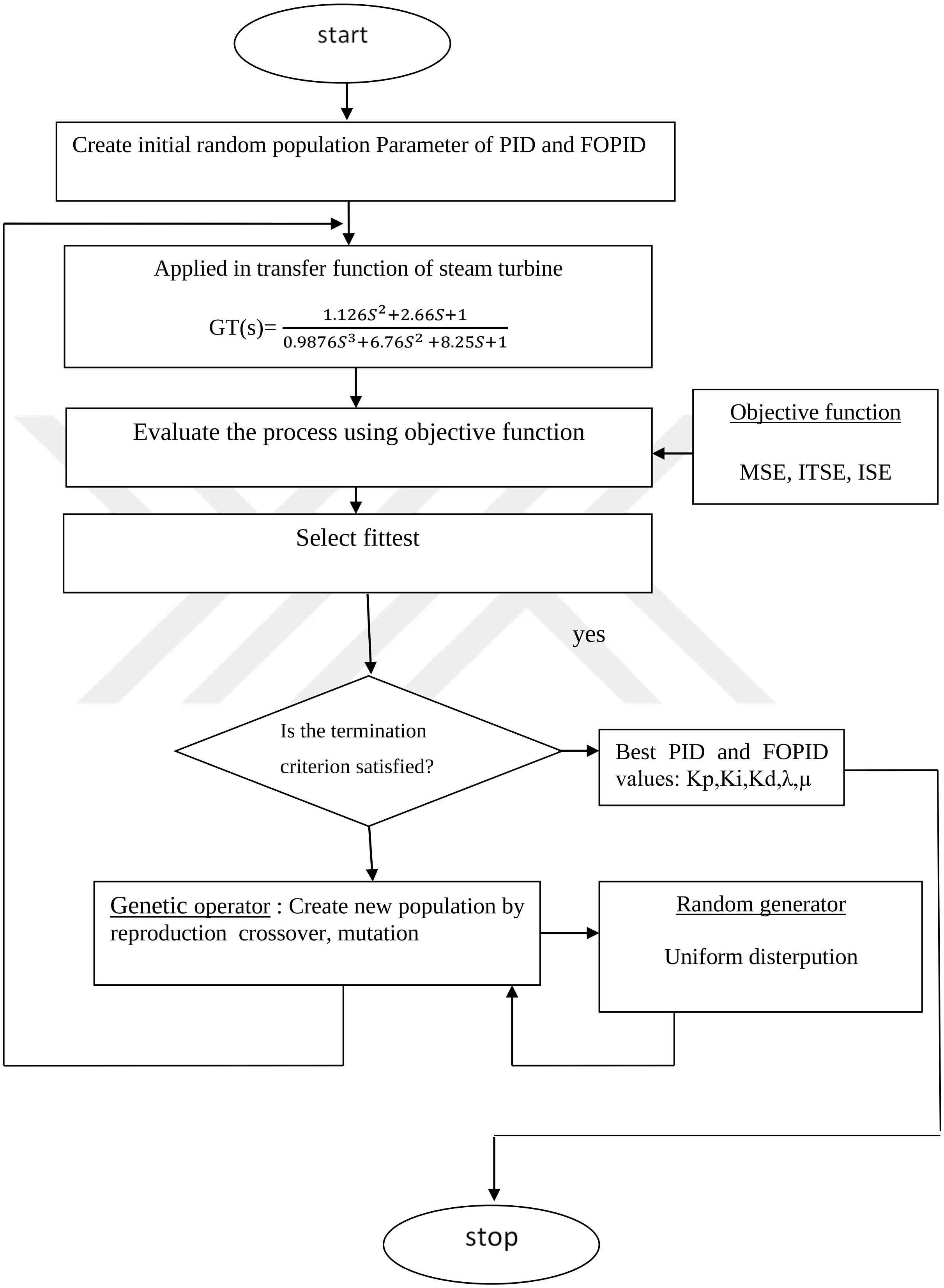

Figure 3.16: Genetic Algorithm with PID and FOPID [51].

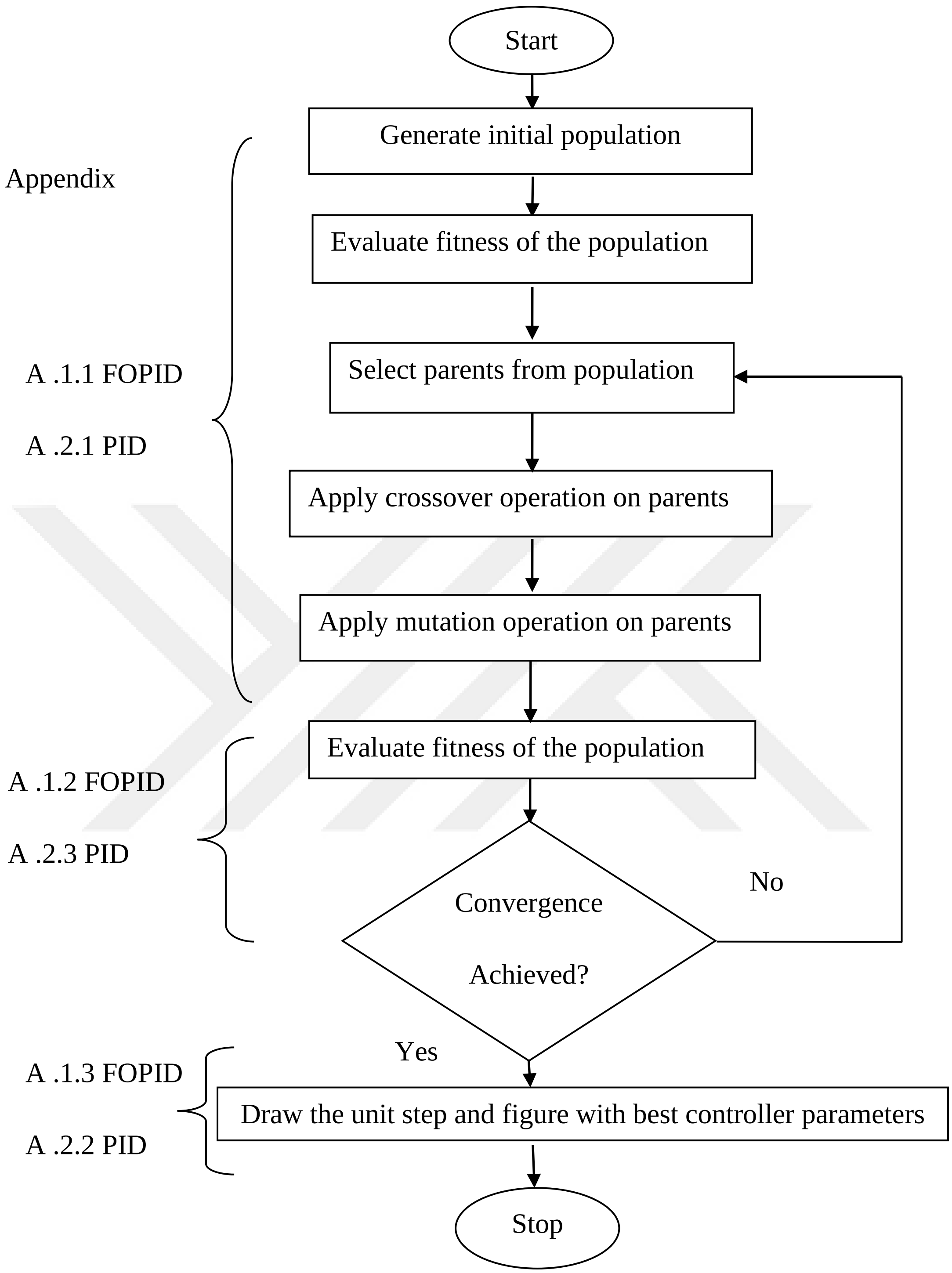

Figure 3.17: Summarize of Genetic Algorithm coding.

The purpose of the study is improving the PID and FOPID parameters to give the best results in the control process, as shown in figure 3.17. Then compare the results of PID and FOPID for the purpose of knowing the best among them depending on the genetic algorithm.

4. FOURTH CHAPTER

4.1 RESULTS AND ANALYSIS

By Using the Matlab program by code in the appendices and using equation (3.21) for the steam turbine based on the genetic algorithm according to figure 3.17, we obtained the following results:

4.1.1 The GA_FOPID ITSE

The table 4.1 explain to us the result that obtain to it when we apply the parameters values

(K_p, K_i, K_d) in table when we use FOPID ITSE method and submit in [64].

Table 4.1: FOPID ITSE results.

K_p	K_i	K_d	λ	μ	Rise Time	Settling Time	Overshoot
119.237	765.544	0.00224	0.595	0.867	0.0162	0.0291	0.294

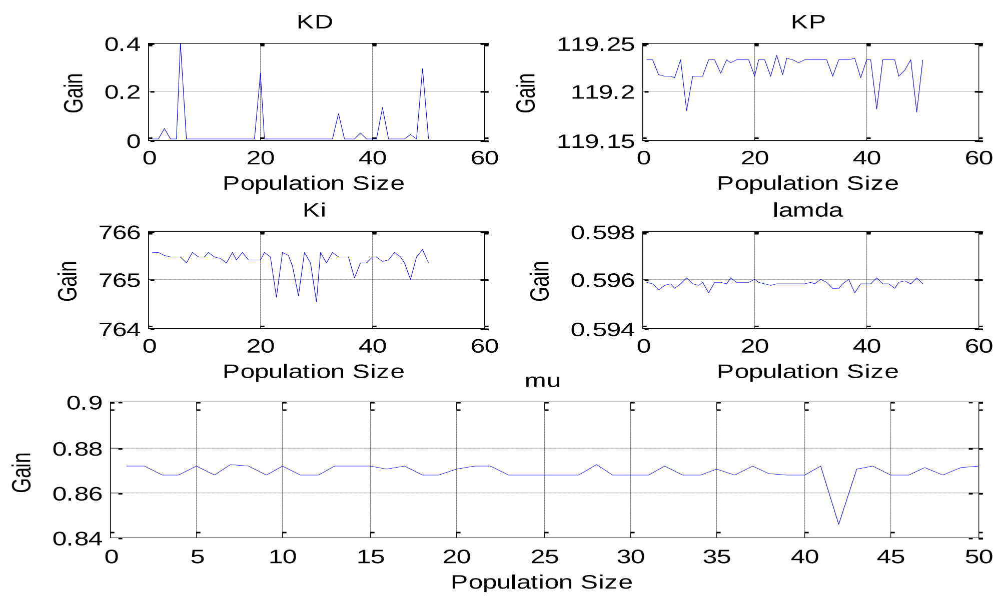

Figure 4.1: The GA_FOPID ITSE parameter.

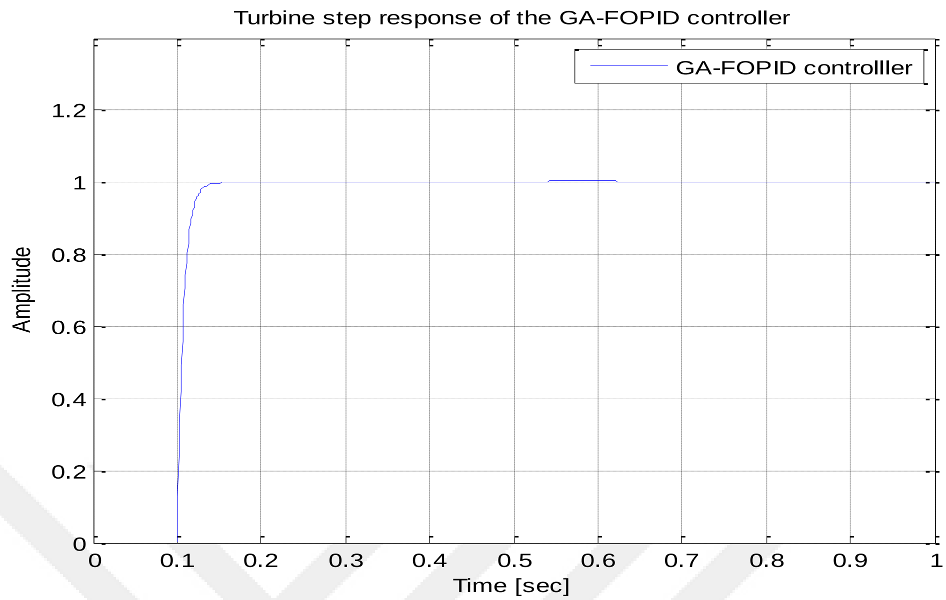

Figure 4.2: Step response of the GA_FOPID ITSE.

4.1.2 GA-FOPID ISE

The table 4.2 explain to us the result that obtain to it when we apply the parameters values (K_p, K_i, K_d) in table when we use FOPID ISE method and submit in [64].

Table 4.2: FOPID ISE results [64].

K_p	K_i	K_d	λ	μ	Rise Time	Settling Time	Overshoot Mp %
100.44	609.875	0.0006512	0.667134	0.789674	0.019187	0.033992	0.365

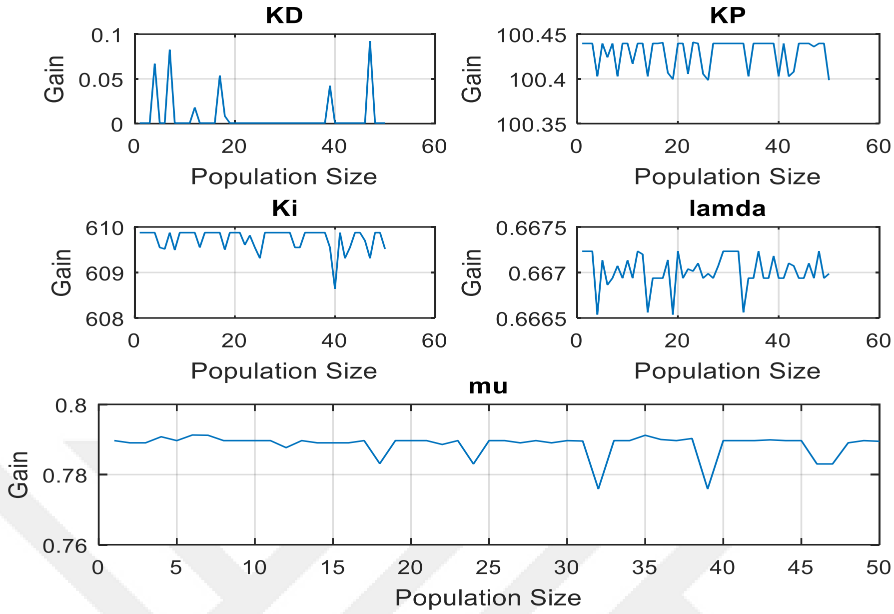

Figure 4.3: The GA_FOPID ISE parameter.

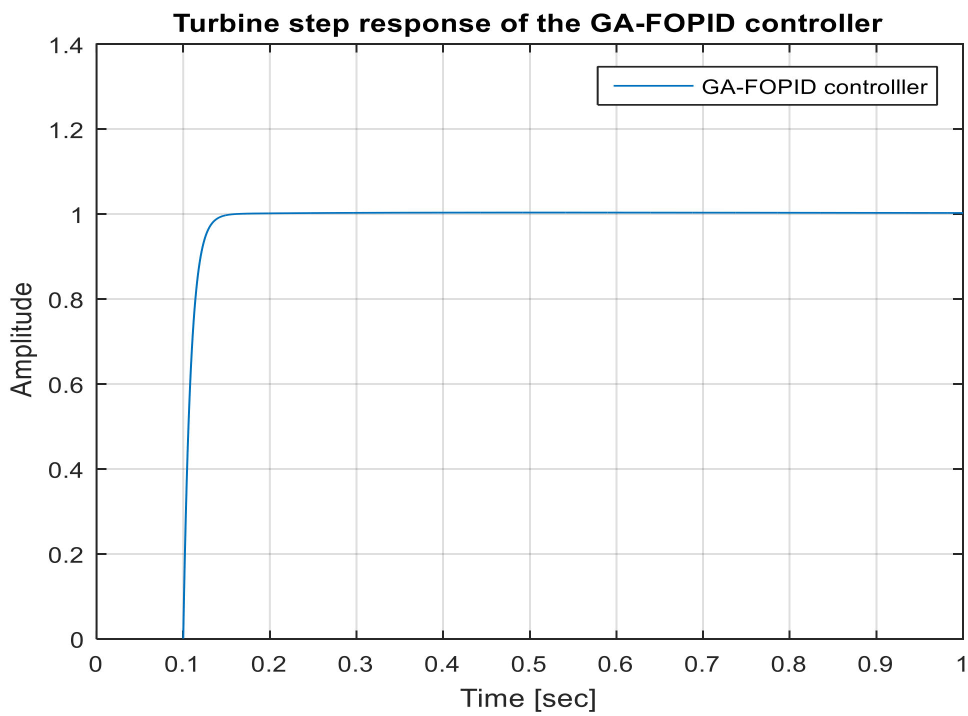

Figure 4.4: Step response of the GA_FOPID ISE.

4.1.3 The GA_PID ISE

The table 4.3 explain to us the result that obtain to it when we apply the parameters values (K_p, K_i, K_d) in table when we use FOPID ISE method and submit in [64].

Table 4.3: PID ISE results.

K_p	K_i	K_d	Rise Time	Settling Time	Overshoot Mp %
24.4658	0.0508777	30.2198	0.763	3.85	30.9

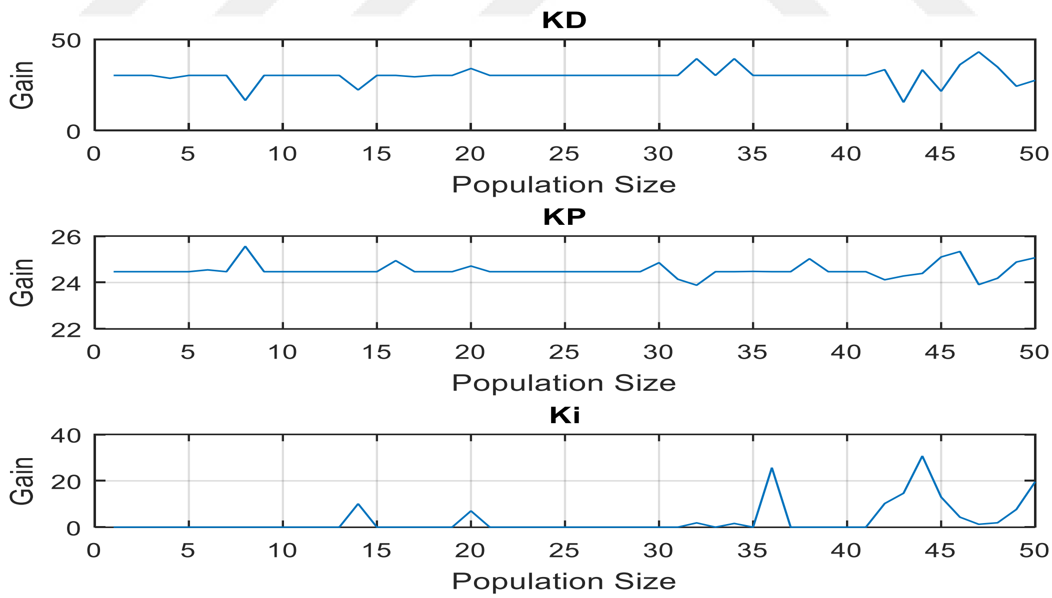

Figure 4.5: The GA_PID ISE parameter.

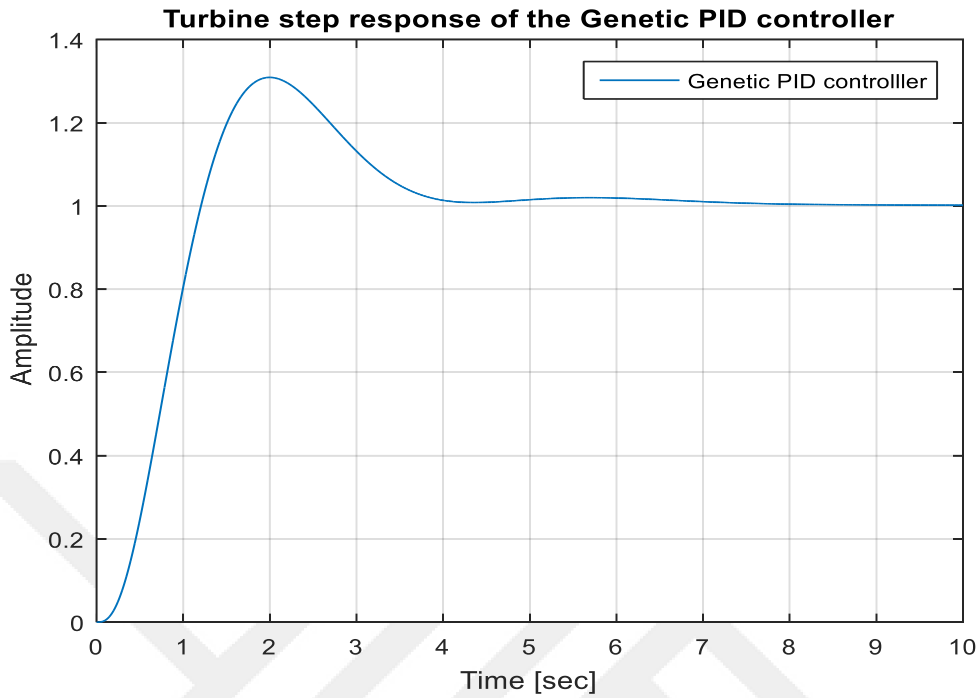

Figure 4.6: Step response of the GA_PID ISE.

4.1.4 GA-PID ITSE

The table 4.4 explain to us the result that obtain to it when we apply the parameters values (K_p, K_i, K_d) in table when we use FOPID ITSE method and submit in [64]**.**

Table 4.4: PID ITSE results [64].

K_p	K_i	K_d	Rise Time	Settling Time	Overshoot Mp %
11.3796	0.0470733	42.4778	0.714	3.26	11.9

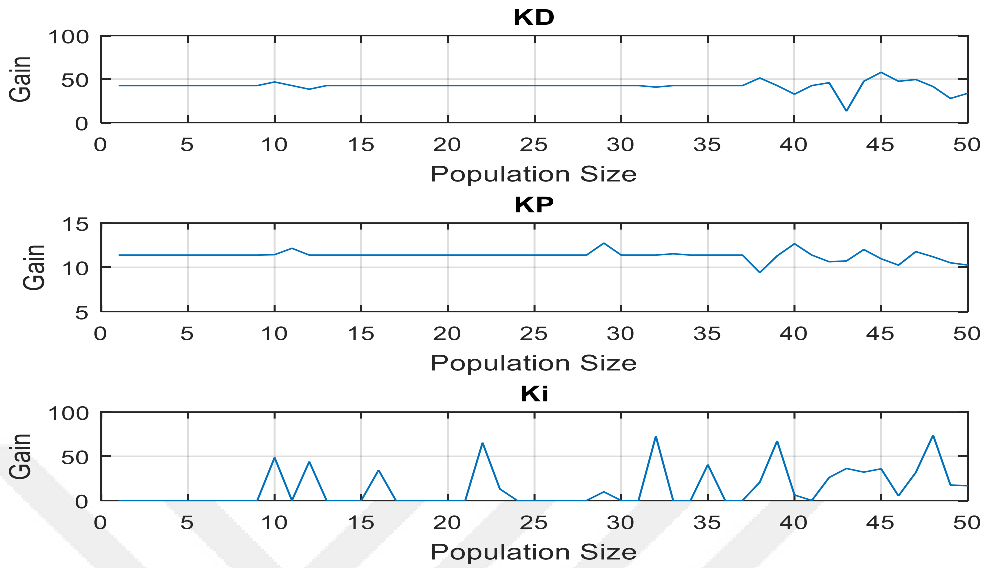

Figure 4.7: The GA_FOPID ITSE parameter.

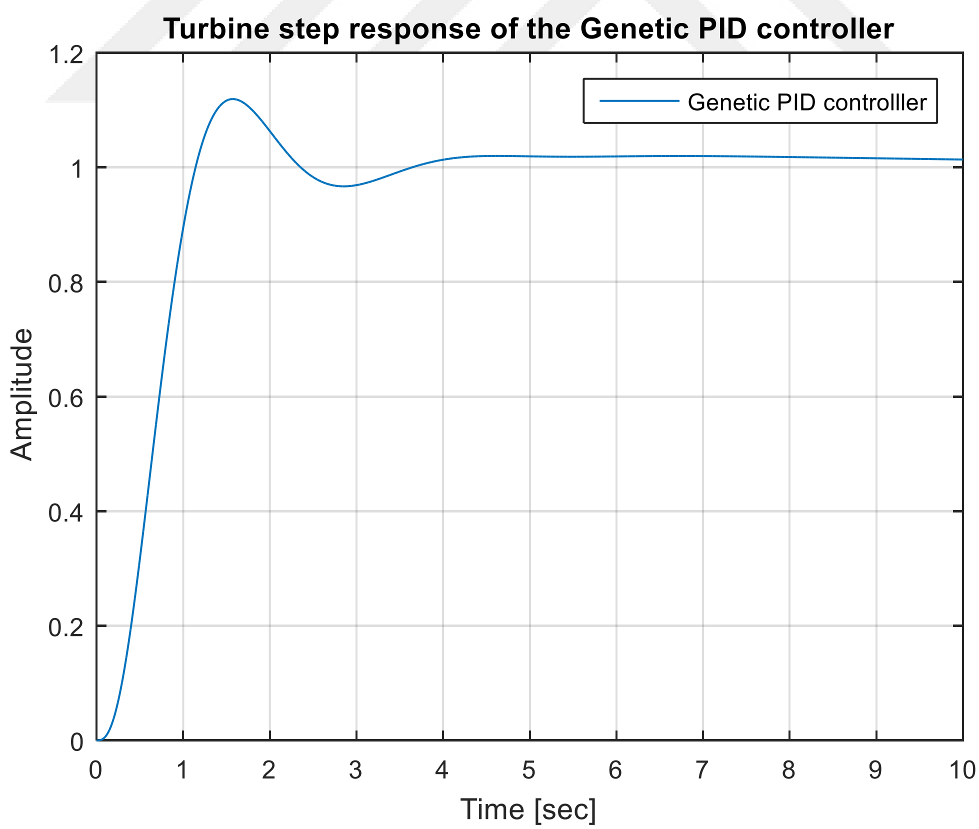

Figure 4.8: Step response of the GA_PID ITSE.

4.2 COMPARISON

Using the genetic algorithm according to the Matlab program codes in the appendix and as shown in Figure 3.17 these parameters were obtained. We will use the table 4.5 the shown below to comparison between all the results.

Table 4.5: Comparison between our results of genetic based on PID and FOPID.

controller type	K_p	K_i	K_d	λ	μ	Tr (sec)	Ts (sec)	Mp %	Population size
GA_FOPID ISE	100.44	609.875	0.00065	0.667134	0.789674	0.0192	0.034	0.365	50
GA-FOPID ITSE	119.237	765.544	0.00224	0.595802	0.867728	0.016	0.029	0.294	50
GA_PID ISE	24.4658	0.0508777	30.21980	-------	-------	0.763	3.85	30.9	50
GA-PID ITSE	11.3796	0.0470733	42.47780	-------	-------	0.714	3.26	11.9	50

The results obtained in this thesis are compared with the results of some previous studies presented in second Chapter, as shown in Table 4.6

Table 4.6: Comparison between our results with previous research.

statue	Reference No.	Tr (sec)	Ts (sec)	Mp %
Our prepared method submitted to [64]	GA_FOPID-ISE	0.0192	0.034	0.365
	GA-FOPID-ITSE	0.016	0.029	0.294
	GA_PID-ISE	0.763	3.85	30.9
	GA-PID-ITSE	0.714	3.26	11.9
Previous studies	Feedback [32]	112	64	
	PI [32]	108	44	
	PID [32]	103	55	
	z-N [39]	0.6	14.9	60
	Y.Lee [39]	1.2	20.4	8
	Proposed [39]	2	7.5	NA
	PID-ZN [40]	295.5		0.36
	PID-AH [40]	391.1		0.19
	PID-CC[40]	255.2		0.353
	PID-CHR[40]	278.3		0.398
	FOPID-ZN [40]	258.6		0.085
	FOPID-AH [40]	182.7		0.088
	FOPID-CC [40]	212.6		0.08
	FOPID-CHR [40]	188.5		0.087
	MOFPA[42]	0.0748	1.0994	0.9413
	LCOA-PID [44]	5.10	9.23	
	GA-PID [44]	5.31	9.42	
	PS-PID [44]	5.18	9.35	
	SA-PID [44]	5.12	9.29	

5. FIFTH CHAPTER

5.1 CONCLUSION

In this thesis, the PID controller is designed to control the speed of a two-stage steam turbine. The genetic algorithm used to improve the parameters of the controller that reduce the effect of integration. Matlab Used to simulate the control process. The previous steps have been repeated on the FOPID controller. By table 4.5 we are conclusion the following:

1. The results achieved using the FOPID control are generally better than the results achieved by the PID by reducing the time of stability and time of elevation and Over shooting, which makes the system performance better.
2. The ITSE (Integral) control method gives better results than the ISE (In) method in both PID and FOPID controllers.
3. The increase in the relative gain (Kp) reduces the time of stability, in other words, the speed of the control system will increase to reach the overall stable state. However, if the increase in Kp is too large, the system will become unstable or may swing out of control.
4. The best method of control in this research is the use of ITSE in the control FOPID, which can be applied in any computer control system.
5. Our results were compared with those of previous studies, from Table 4.6 on the basis that the lower the Tr, Ts the better the results, and we show that the results obtained, better than the results of the search [32] in terms of Tr, Ts, as well as the method FOPID-ITSE In this thesis gives better results than the search [39], as well as all the results in the thesis better than all the results of [40]and[44] in terms of Tr, Ts.

5.2 FUTURE WORK

Future work will be improved steam turbine speed control by comparing the performance of the FOPID controller with two degree of freedom FOPID controller and the best application, will be apply it on programmable logic controller (PLC).

6. SIXTH CHAPTER

6.1 OUR CONTRIBUTION

We summarized the previous studies on steam turbine speed control, which are presented in the second chapter, as form of a table 6.1 showing the type of controller, the technique used and a summary of the conclusion of the study. The purpose of knowing the controllers and techniques that need more attention to be studied.

Table 6.1: Summary of previous studies for comparison.

Resource Number	Controller	Technique	Findings
[23]	A small computer	Least-Squares or maximum-likelihood algorithm.	Gave better results when it underwent a change in load.
[24]	FNN controller	Neural network	Applies to complex and modeling process reasoning.
[25]	PID controller	New hybrid algorithm DEPSO.	Effective method of parameter identification in the system of steam turbine regulation.
[26]	PID controller	PSO, genetic algorithm and fuzzy neural network.	The program provides a variety of optimization algorithms and parameters in the linear and nonlinear parts.
[27]	Fuzzy self-tuning PID and apply	The new technology achieved fuzzy self-adjusting.	fuzzy self-tuning PID speed control has better speed and stability than the traditional PID speed control.
[28]	self-tuning adaptive turbine controller	(Least-Squares Estimation (LSE) and minimum-variance control) techniques.	Control of the frequency change resulting from the change of speed in the generator may be reduced or avoided.
[29]	The controller is a PLC system, used readily available PLC components.		The programmable logic controller (PLC) offers greater flexibility in turbine control and is also more flexible, It has ready-made parts and controls that are easier to use and cheaper than others.

Resource Number	Controller	Technique	Findings
[30]	H∞ controller	algorithm of Hybrid sensitiveness index optimization on H∞	The error is less and Reduces or ends the disturbance with the H∞ robust than PID control algorithms.
[31]	PID controller	fuzzy system and genetic algorithm and each of the PSO, ANFIS and BPSO algorithms.	The Adaptive Fuzzy PID is better than the other AI in reduce time and the BPSO designed better than the classic and designed by both GA and PSO in terms of response.
[32]	Adaptation use of different controller as Feedback, PI, PID	Massachusetts Institute of Technology (MIT)	Indicated in Simulation results PID controller it was had better response than a PI and feedback controller. The fixed error in feedback response was completely castaway by the use of PI controller.
[33]	visual C ++ program.	Used mathematical model of marine turbines system.	The goal of this process is to train mariners and teach students in universities and it can implement and save cost, certain application value.
[36]	PID controller 2-DOF-FOPID	Firefly algorithm (FA) compared with PSO, BFO and ABC algorithms.	The DOF-FOPID is superior in terms of Stability time and less disturbance as the superiority is enhanced by the PSO, BFO and ABC to confirm.
[39]	PID controller	The new internal control model (IMC), Y. Lee et.al. and Ziegler-Nicholas for comparison.	Using the IMC technology for the purpose of PID tuning can enhance system control better by improving rise time, settling time, peak overshoot.

Resource Number	Controller	Technique	Resource Number
[41]	self-adaptive PID fuzzy		It was able to maintain the turbine rotation speed as set point, also good in terms of RMSE and varies slightly in load changes.
[42]	FOPID controller	Multi-objective variant of flower pollination algorithm (MOFPA)	This method gives stability to the system and provides efficient control.
[43]	P and PI controller	Proportional and proportional-integrative control algorithms.	Steam turbines can provide good speed stability with the right speed controllers.
[44]	PID controller	LCOA map-based chaotic algorithm	The optimal PID is capable of solving the LFC problem and the LCOA-PID results were better in each region.
[45]	PID controller	Chaotic particle swarm optimization modified algorithm (CPSO)and RBF neural network self-tuning.	The control system can be very precise and has good dynamics, this strategy enables effective control of the complex object and creativity in the work and achieve practical application.
[46]	fuzzy PID controller	Mathematical model (a differential evolution).	, including small overshoot, high durability and rapid response compared to the traditional PID control.
[47]	PID controller	Combines both the particle swarm optimization and the lower squares algorithms.	The neural network can be used in modeling the speed control system for energy system stability studies.
[48]	MPC,PID and fuzzy PID controllers	Ziegler and Nichols proposed method and fuzzy self-tuning PID	The MPC controller could improve compared to the conventional PID and fuzzy PID is better for steam turbine speed control.

After reviewing the previous studies, we observed little attention in control with the fractional order PID using the genetic algorithm. Therefore, in this thesis, we studied the use of both FOPID and PID and adjusted them by the genetic algorithm to control the speed of the steam turbine to see which gives the best results, we concluded. The results achieved using the FOPID control are generally better than the results achieved by the PID, by reducing the time of stability, time of elevation and over shooting, which makes the system performance better. The ITSE control method gives better results than the ISE method in both PID and FOPID controllers. The best method of control in this research is the use of ITSE in the control FOPID, which can be applied in any computer control system.

Our conclusions are good compared to those obtained in previous studies, which enhance improved automatic-control of the steam turbine speed.

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APPENDIX A

MATLAB CODE

A.1 FOPID CODE

A.1.1 Start

```
%%%%%%%%%    Iterating the genetic algorithm
clear
clc
format long;
options = gaoptimset('PlotFcns',...
         {@gaplotbestf});
[X,endPop,bPop,traceInfo,population] = ga(@FOPIDC,5);
t=0:0.001:1;
y=FOPIDY(X,t);
fprintf(' Kd = %g \n',abs(X(1)));
fprintf(' Kp = %g \n',0.1*abs(X(2)));
fprintf(' Ki = %g \n',abs(X(3)));
fprintf(' lamda = %g \n',0.001*abs(X(4)));
fprintf(' mu = %g \n',0.01*abs(X(5)));

figure(1)
plot(t+0.1,y);
xlabel('Time [sec]')
ylabel(' Amplitude')
legend('GA-FOPID controlller ')
title(' Turbine step response of the GA-FOPID controller ')
grid
axis([0 1 0 1.4])
figure(2)
d=1:1:length(population);%%%%%%%%%%%%%%%%%%%%%%%%%%
subplot(3,2,1),plot(d,abs(population(:,1)))
title('KD'), ylabel('Gain');xlabel('Population Size');grid
subplot(3,2,2),plot(d,0.1*abs(population(:,2)))
title('KP'), ylabel('Gain');xlabel('Population Size');grid
subplot(3,2,3),plot(d,abs(population(:,3)))
title('Ki'), ylabel('Gain');xlabel('Population Size');grid
subplot(3,2,4),plot(d,0.001*abs(population(:,4)))
title('lamda'), ylabel('Gain');xlabel('Population Size');grid
subplot(3,2,[5,6]),plot(d,0.01*abs(population(:,5)))
```

```
title('mu'), ylabel('Gain');xlabel('Population Size');grid
```

A.1.2 FOPID C

```
%%%%%      FOPID_objfun_mse.m         %%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function F=FOPIDC(X)
Kd=abs(X(1));
Kp=0.1*abs(X(2));
Ki=abs(X(3));
lamda=0.001*abs(X(4));
mu=0.01*abs(X(5));
 t =0:0.001:1;
 ncl = [Kd*gamma(lamda+mu)  Kp*gamma(lamda)  Ki];
dcl=[gamma(lamda)  0];
np=[1.126    2.66     1];
dp=[0.9876    6.76    8.25    1];
n=conv(np,ncl);
d=conv(dcl,dp);
s = tf(n,d);
s1 = feedback(s,1);
 S = stepinfo(s1)
if S.RiseTime < .01
    RT = 1 ;
else
    RT = 1000 ;
end
if S.SettlingTime < 1
    ST = 1 ;
else
    ST = 1000 ;
end
if S.Overshoot < 12
    OV = 1 ;
else
    OV = 100 ;
end
 F =S.RiseTime*RT + S.SettlingTime * ST + S.Overshoot*OV;

if X(1)<0

    F=1e7;
End
```

A.1.3 FOPID Y

```
%%%%%%%%%Plotting Genetic algorithm controller  %%%%%%%%
function y=FOPIDY(X,t)

Kd=abs(X(1));
Kp=0.1*abs(X(2));
Ki=abs(X(3));
lamda=0.001*abs(X(4));
mu=0.01*abs(X(5));

t =0:0.001:1;
ncl = [Kd*gamma(lamda+mu)  Kp*gamma(lamda)  Ki];
dcl=[gamma(lamda)  0];
np=[1.126   2.66     1];
dp=[0.9876    6.76   8.25   1];
n=conv(np,ncl);
d=conv(dcl,dp);
s  = tf(n,d);
s1 = feedback(s,1);
y  = step(s1,t);
```

A.2 PID CODE

A.2.1 Start

```
%%%%%%%%%%%% GA-PID Controller
t=0:0.001:10;
y  = step(s1,t);
Kd = 30.2198 ;
 Kp = 24.4658 ;
 Ki = 0.0508777 ;

%  Kd = 42.4778
%  Kp = 11.3796
%  Ki = 0.0470733

n1  = [Kd Kp Ki] ;
d1 = [ 1 6 5 0 0];
np=[1.126    2.66     1];
dp=[0.9876    6.76   8.25   1];
```

```
n=conv(n1,np);
d=conv(d1,dp);
s  = tf(n,d);
s1 = feedback(s,1);
figure(1)
plot(t,y);
xlabel('Time [sec]')
ylabel(' Amplitude')
legend('Genetic PID controlller ')
title(' Turbine step response of the Genetic PID controller ')
grid

figure(2)

step(s1,t)
% step(s,t)
```

A.2.2 PoleAssignY

```
function y=PoleAssignY(X,t)

Kd=X(1);
Kp=0.1*X(2);
Ki=3*X(3);
n1  = [abs(Kd) abs(Kp) abs(Ki)] ;
d1 = [ 1 6 5 0 0];
np=[1.126    2.66     1];
dp=[0.9876    6.76   8.25   1];
n=conv(n1,np);
d=conv(d1,dp);
s  = tf(n,d);
s1 = feedback(s,1);
y  = step(s1,t);
```

A.2.3 Pole Assign

```
function F=PoleAssign(X)
Kd=X(1);
Kp=0.1*X(2);
Ki=3*X(3);
```

```
t =0:0.001:10;
n1  = [abs(Kd) abs(Kp) abs(Ki)] ;
d1 = [ 1 6 5 0 0];
np=[1.126    2.66     1];
dp=[0.9876    6.76   8.25   1];
n=conv(n1,np);
d=conv(d1,dp);
s = tf(n,d);
s1 = feedback(s,1);
 S = stepinfo(s1)
if S.RiseTime < .01
    RT = 1 ;
else
    RT = 1000 ;
end
if S.SettlingTime < 1
    ST = 1 ;
else
    ST = 1000 ;
end
if S.Overshoot < 12
    OV = 1 ;
else
    OV = 100 ;
end
 F =S.RiseTime*RT + S.SettlingTime * ST + S.Overshoot*OV;
 if X(1)<0

    F=1e7;
end
```