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BYPASSING THE SIGNAL IMPERFECTIONS BY MEANS OF WIRELESS PID CONTROLLER

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Supervisor Prof. Dr. Osman Nuri UCAN

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BYPASSING THE SIGNAL IMPERFECTIONS BY MEANS OF WIRELESS PID CONTROLLER

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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 Engineering.

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DEDICATION

I dedicate this thesis to my family, classmates and all my friends for the support and encouragement throughout my education and life. Special dedication goes to my supervisor Prof. Dr. Osman Nuri Ucan, my sisters and my mother for their support and prayers during my research work.

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I might want to offer my thanks to every one of the individuals who have upheld me all through the regularly extended periods of this voyage. I might want to thank my advisor, Prof. Dr. Osman Nuri Ucan for being my compass notwithstanding when I believed I was lost and being in extraordinary part in charge of the zenith of this work. I might likewise want to thank my supervisors for their supportive exhortation, which incredibly enhanced the nature of this work. Finally, I thank this institution for hosting me during these years, securely earning its place as my home. I am very thankful to my mom and dad, whose values and education motivate me to keep asking questions; to my siblings and family for their infinitely appreciated love and to my country which, although inanimate, keeps me anchored and offers me an example of resiliency.

ABSTRACT

BYPASSING THE SIGNAL IMPERFECTIONS BY MEANS OF PID CONTROLLER

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To achieve the continuation of industrial operations of all kinds, the engineers and designers considerable effort for improving the performance of the wired and wireless controllers, that can PID controller device be a best of them, where operation basic theory depends on the proportional (P), Integral (I) and derivative (D) mathematical logic in order to decides a data that make the control in process more reliability with much effectiveness. In many of PID applications, the controller be too far from monitoring room, and most often a device is wireless to reduction of deployment and maintenance costs, large flexibility and possible keeping of safety. But many challenges are facing the required performance of operation such as time delays and packet loss which regarded as a big challenge and needs to be solved. This study will focus on dependence of the controller on itself to bypass wireless transmission problems by adopting the principle of comparing between the data which have been measured (by sensor) and received (by wireless equipment), where the introduced system consists of microcontroller which presents the heart of proposed system and RF link.

Keywords: Wireless PID controller, Wireless networks imperfections, Programmable microcontroller, Tuning theory of PID parameters, PID controller.

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LIST OF ABBREVIATIONS

PID : Proportional, Integral and Derivative Controller

WNCS : Wireless Networked Control Systems

LAN : Local Area Network

TCP : Transmission Control Protocol

AQM : Active Queue Management

PI : Performance Index

IMU : Inertial Measurement Unit

PWM : Pulse Width Modulation

MIMO : Multiple-Input and Multiple-Output

AUV : Autonomous Underwater Vehicle

PSO : Particle Swarm Optimization

CSA : Cuckoo Search Algorithm

FFA : Firefly Algorithm

DSP : Digital Signal Processing

MBPC : Model Based Predictive Control

LQR : Linear Quadratic Regulator

MBPC : Model Based Predictive Control

FLC : Fuzzy Logic Control Technique

RL : Root Locus

TDC : Time-Delay Controller

ISE : Integral Square Error

1. INTRODUCTION

The continuation of industrial operations of all kinds is a goal for engineers and designers. To achieve this, considerable efforts have been made in this regard. Most of these efforts were focused on improving the performance of the controllers, where the PID controller was the best between the others.

1.1 PID CONTROLER DIFINITION

PID controller is using widely in industrial applications due its simplicity and reliability, where can be used for regulation of speed, temperature, flow, pressure significantly add to other processes variables.

The basic theory of PID controller is depending on the proportional (P), Integral (I) and derivative (D) mathematical logic in order to decides a data that make the available anatomical controller more reliability with much effectiveness.

The PID controller will estimated the error value e(t) fundamentally, depending on the difference of set value with the value which be measured every time . Afterwards, the controller enforce the mathematical logics of the three terms (proportion, integral and derivative) and implement the reaction to correct or decreases the error and creates the optimal controller output that will make the process continues as required.

1.2 THE WIRELESS PID CONTROLLER

It is known that in many of PID applications, the controller be too far from monitoring room, and most often a device is wireless to reduction of deployment and maintenance costs, large flexibility and possible enhancement of safety, so the Wireless networked control systems (WNCS) are becoming a fundamental infrastructure technology for critical control systems in automotive electrical systems, avionics control systems, building management systems, and industrial automation systems.

The basic action steps of the wireless PID controller can be explain in figure 1.1, Where the reactive variables for control and communication systems, containing the taking period of samples, time delay of messages, data dropout, and large consumption of the energy transmission, while The Design Mechanism of Wireless Network for Control System, presents different improvement techniques for wireless communication networks which can be integrating with the control systems [1].

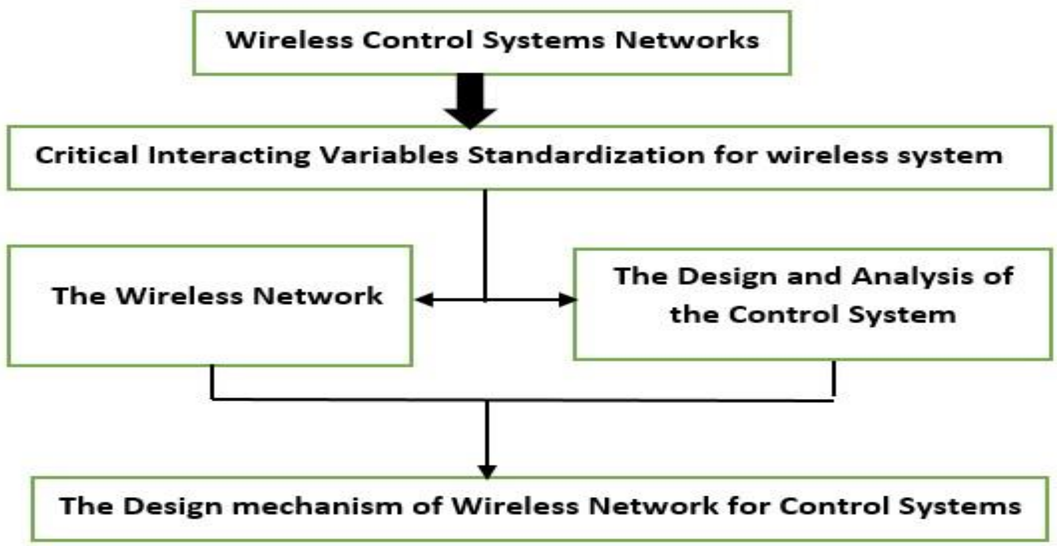

Figure 1.1: Action Steps of the Wireless PID Controller

But, there are many challenges which could arise in wireless communications which is represented by the inherent time varying delays and packet dropouts [2]. The time delay in wireless networked control system (WNCS) which using the Wi-Fi, is one of the serious problems in control engineering, where it cause the system unstable in case that there is a large time delay in closed control loop [3], because it will decreases the controlled system phase margin [4]. For example, wireless LAN protocol is not suitable for the remote control, because of interference problems and large and unstable transmission latency [5]. Therefore, the continued control of a particular wireless industrial processes in case of interruption or loss in signals, much slow updating of wireless measurement or any other possible problems between the source and device, is a big challenge of designers and searchers.

In contrast, in the artificial intelligence application groups, mathematical methods and the lack of a sound theoretical foundation is regarded as a big challenge and needs to be solved [6].

1.3 NEW AREAS APPLICATIONS OF WIRELWSS PID CONTROLLER

Today, some researchers went further in trying to use it in information technology fields, by design it with time-varying parameters to control the congestion in transmission control protocol (TCP) networks, where the developed PID controller is based on active queue management (AQM) by using D-partition technique [7].

Other studies proposed a new formation control and new methods to avoid an obstacle for the swarm robot systems (SRS) dynamic area in order to improve its ability to implement the formation by rotating and scaling during the movement through adopting Gradient Descent formula in order to updates the robot orientation vector and the range for the systems of swarm robot [8].

1.4 RESEARCHER'S EFFORTS AND OBJECTIVES IN THE FIELD OF PID CONTROLLER

There is so much interest by the academics and manufacturers in PID modifications that may improve performance and tools which facilitating the control on plant and monitor of performance for unconstrained operation of stationary and linear processes. In the other side, it is be focusing on increase the utilization of multi-loop and single loop control based on PID taking into account constraints non-linearity and operational for process [9]. Several studies have focused on improving the performance of the communication system of the device while other studies focusing theoretical side to overcome the difficulties associated with the traditional PID tuning methods to meet various demanding, specifications and to shorten the time required to achieve stability, while it is known the direct optimization of the PID gains often lead to a nonconvex problem [10]. while other studies focused on automatic tuning of these parameters such as Adaptive control, which provides systematic approach for automatic adjustment of controllers in real time, in order to achieve a desired level of control performance when the process dynamic model parameters are change in time and/or be unknown, where measures a the control system performance index (IP), and From comparing the measured performance index and a set of given ones, will modify the adjustable parameters of the controller and/or generates an additional control to maintain the performance index within the set of acceptable ones [11], and so on.

It seems that in the next few years, PID controller will be smarter and will stay the main workhorse of process industry control [8].

This thieses will focus on dependence the controller on itself to bypass wireless transmission problems by adopting the principle of comparing between the data which have been measured and recieved, where the introduced system consists of microcontroller which be the heart of proposed system and RF link.

The couple data (measured value and desired value) which is transmitted by wireless equipment from control room and the second data (measured value) are feded to the microcontroller by the sensor, as shown in figure 1.2.

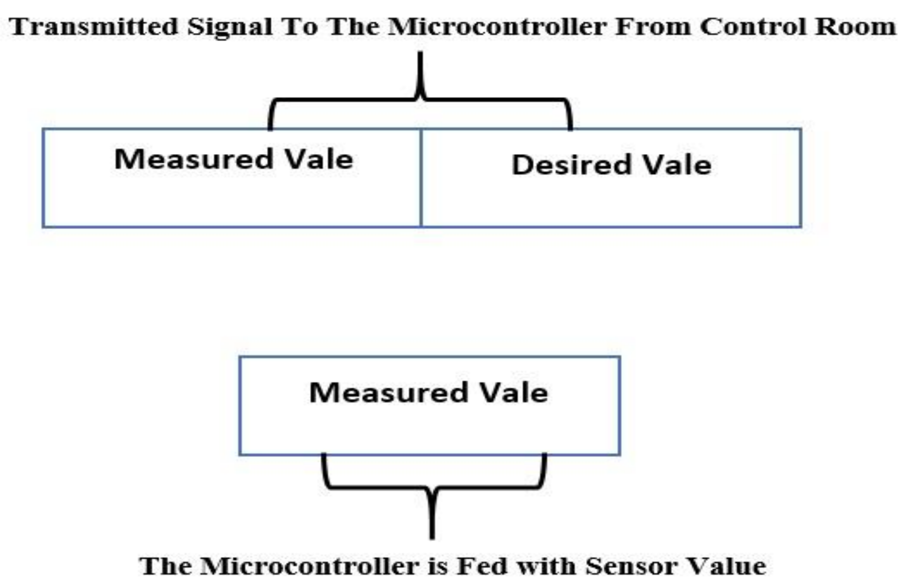

Figure 1.2: Transmitted Values and Measured Values which will be compares

2. BACKGROWNED

PID controller is still the most widely used in industrial processes because of its high reliability and simplicity.

In many applications, the PID controller is too far away from the control room. Therefore, when the device be is wireless, this will reduce deployment and maintenance costs, improve security, and provide the ability to enhance work to achieve optimal operation performance.

However, the wireless PID controller is not free from some of the disadvantages that effects on the performance, such as the time delay of messages, data leakage, and the large consumption of power transmission.

2.1 IMPORTANT ASPECTS FOR PID PERFORMANCE

This section will attempt to cover some of the aspects addressed by the researchers during their studies for wireless PID controller.

Each subsection will highlight one important aspects of the wireless PID controller, which plays an important role in the improvement of control system performance.

2.1.1 Studies Interested in Controller Design

It’s clear from the studies that highlighted the PID controller design, searching of use different equipment to achieve fundamental logic of three terms for PID controller, which is (proportional, integrated and derivatives) or addressed to algorithms development in order to reach the perfect principles of PID controller.

The two searchers Viswanadhapalli Praveen and Anju S. Pillai by depending on the fundamental principles of PID (Proportional Integral Derivative) controller proposed remote controlled quadcopter system which is builds by using IMU (Inertial Measurement Unit).

The IMU contains accelerometer and gyro sensors in order to calculate the system direction and velocity control for four BLDC motors which will make the quadcopter able from flying in different six trends.

In the quadcopter that contains four motors to rotate it in clockwise and anticlockwise direction, the wireless equipment receives the PWM (Pulse Width Modulation) signals that is fed to controller.

Ardupilot Mega board is utilized which contains ATMEGA 2560 controller and according to PWM signal which is sends to the motors.

Once the four motors spin, the quadcopter will hover in air with much stability.

The two searchers implemented the PID logic by using MATLAB Simulink model successfully optimal desired outputs by using PID controller [12].

While Mohammad Hedayati Khodayari Saeed Balochian focused in them study on design of a proposed selfadaptive fuzzy PID controller depending on nonlinear MIMO (multiple-input and multiple-output) construct for an AUV (Autonomous Underwater Vehicle).

In order to overcoming the AUV modeling process intricacy because of much of combined dynamics, variance of the time, and difficult simulation and hydrodynamic modeling , and the design of suitable and optimal controller they suggested derivation nonlinear model of AUV during of kinematics and dynamic equations.

Them simulation results insure that proposed control system is stable and effective sufficient to dominance the AUV and can provides premium dynamic, robust stability and stunning steady-state properties [13]. The figure 2.1 explain the block diagram of suggested PID controller.

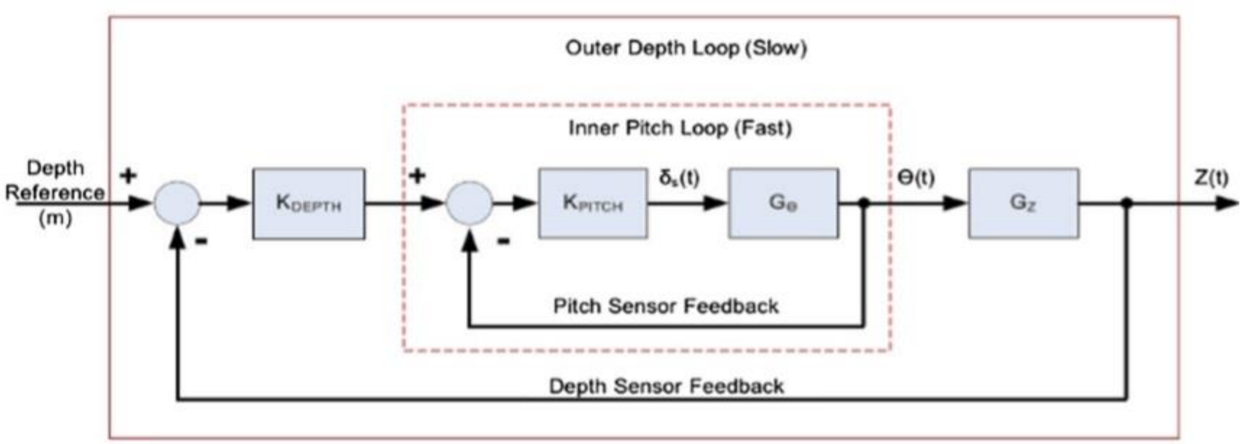

Figure 2.1: The main block diagram of the suggested PID strategy for AUV [13]

The third studies which was be showed for (Mirza Muhammad Sabir and Tariq Ali), where they considered the designing of an optimum (PID) controller for DC motors that is using in tracker system of dual axis solar.

In these systems, it is important to implement accurate tracking system of the sun and of its tilt angle based on three metaheuristic algorithms, which is PSO (particle swarm optimization), CSA (Cuckoo Search Algorithm) and FFA (firefly algorithm) to build PID controller system.

The study explained that CSA is excellent as compared to FFA and PSO where it's convergence rate was faster, and standard deviation very small

They pointed to the sequel of this work will be by implement of the control algorithm designed in this work. This will be very effective solution for dual axis solar trackers [14].

The authors (Chunsheng Wei and Dirk Söffker) proposed algorithms, strategy and calculations from implementation of AMB (active magnetic bearing) controller in order to bypass the time-consuming iterative that happen when manual tuning procedure to design this shape of PID controllers.

AMB system controller was designs and needed results are goten by using the optimal combination for time-domain- and frequency-based , in add to a estimation theory for fitness functions for the complicated design of this PID-controller , with reduction of sensitivity-based parameter to achieve the required optimization.

So that, the proposed PID was more complex than typical PID controller depending on optimization strategy which was reflected to structure.

In the optimization strategy centralized control is necessary, where can separate the conical and parallel modes for the rotor, in add to possibility the design of corresponding controller.

Before transmitting of sensor signals to the digital signal processing (DSP)unit for the suggested control device, it's had to separate the modes of rotor to parallel modes and other which is tilted, by changed to modal coordinates from sensor coordinates. The proposed controller can be shown in figure 2.2 [15].

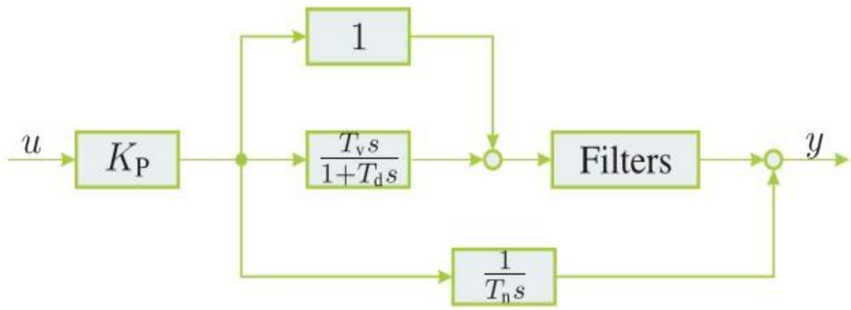

Figure 2.2: AMB System PID Controllers Block Diagram [15]

2.1.2 Studies Interested in Wireless System Principles of PID Controller

The studies focused on the imperfects that may result by employing of wireless networks such as delay time and the dropout of transmitted data or those troubels that may be result by using thousands of sensor networks and so on.

The searchers (Rahul Vijayan, P.P. Praseetha, Dwain Jude Vaz and V. Bagyaveereswaran) suggested in their paper, a theoretical framework for controlling has the ablility to deals with time-delayed system by employing Smith predictive PID controller which is based on fuzzy logic.

In the nonlinear systems the traditional PID controller will be not effective where the overshoot will reachs high values. Therefore,

Using of combination of Smith predictor with fuzzy logic controller can give perfect response of the system after bypassing this imperfects.

In systems, the delay in the time may be because of mass transportation phenomena, time of the processing or collections of time lags of connected systems togother.

Depending on Smith predictor, dead time is recovered . With using of Smith predictive PID controller the high peak overshoot will be reduced and will increase the oeffectivity of the performance .

Optimization of PID controller by using LQR (Linear Quadratic Regulator) algorithm will help to reduce settling time and improve the implementation [16].

While (Mercedes Chac´on V´asquez Reza Katebi) are presented four new expected algorithms for control in order to compensate the dropout that is happeneds in wireless networked control systems. their theory depends on the MBPC (Model Based Predictive Control) with PID control templet.

In order to achieve the stability, a Kalman filter will be adds to the control scheme in case of transmitted data dropouts from sensor to the PID controller to ensure reliability on the Wireless Networked Control Systems (WNCS).

The proposed idea are also can be use to compensate the dropouts between the controller and actuator which help to raise the systems effectiveness.

The proposed control system which shown in figure 2.3 is presented by the block diagram of the depicted.

The dropout in transmitted signals between sensor and controller and between controller and actuator are represented as dpsc (Density Peak Spectral Clustering) and dpca (Dynamic Principal Components Analysis), respectively. The output of the sensor (ys) is switched to the Kalman apreciation (ye) which will allowing the control system to have information every time during the process even the case of dropout in the data. Four predictive PID controllers depending on MBPC scheme.

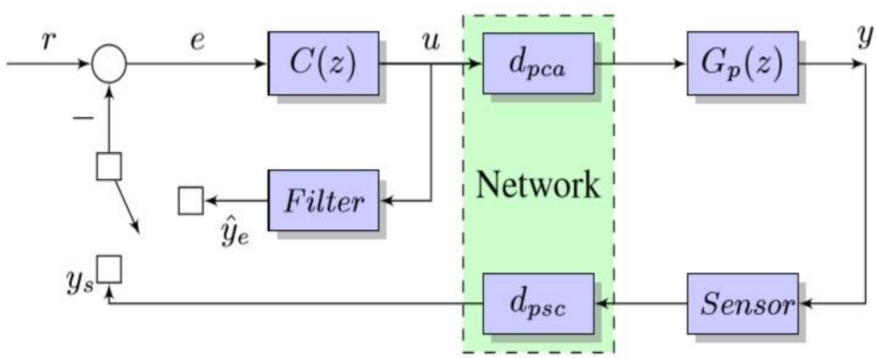

Figure 2.3: The Bloack Diagram of predictive PID controllers structur [17]

The results of proposed four algorithims with PID controller insured the effectiveness of the predictive controllers for WNCS (wireless network control system) after combaining between control theory and Kalman filter togother to compensate for dropout which be in transmitted data and succeeded in implementation of control actions with high stability and flexibility during support the this predictive PID controller [17].

The third study which be highlight on it for (D. Pamela and M. S. Godwin Premi), where they discussed the challenge which is represented in maintain the perfect degree of temperature in hot air ovens that uses dry heat to sterilize the syringes and surgical equipments, depending on remot control process which will be so important in this area, where Ethernet cables using in order to transmit the measured value as a data between the process and the controller device and control desired value depending on transmitted signals between controller and the process, what it requires

Therefore, in order to eases the work and to reduce the costof same these process with optimal temperature, they proposed deploying the controller ain more remote area and the signals were transmitted between the wireless PID controller and Ethernet cable for development of different temperature control ways in hot air ovens.

During the time of closing the conventional feedback control system via a wireless connection channel, which can be shared with another nodes that acts outside for the control system, then the control system can be considered as a shape of a networked control system (NCS).

When the transmitted data is transfer between the inside and ouside nodes and are routed by using a wireless router then the communication system becomes a wireless network as shown in figure 2.4.

By simulating the adaptive Smith predictor with using matlab The adaptive shape of proposed wireless controller, which gave the better behavior for implemetation through real-time [18].

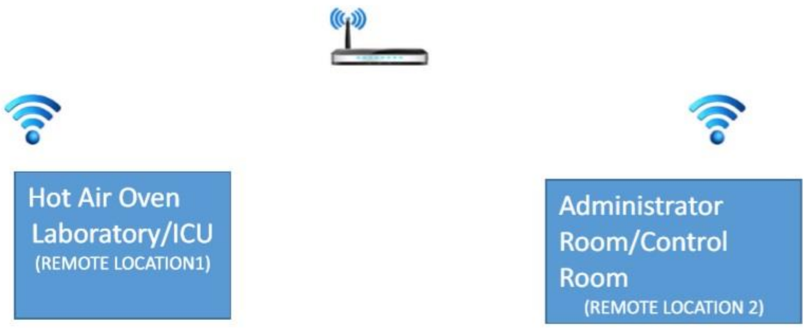

Figure 2.4: Wireless communication system for hot air oven with PID controller [18]

In the fourth study in this sections (Pouria Zand , Supriyo Chatterjea, Kallol Das and Paul Havinga) highlighted on wireless technologies generally used in the areas of monitoring and control and whta's the pros and cons for every technology and the degree of ability for each of them for meeting the high requirements of industrial monitoring and wireless control networks. In addition to, explaine the suggested mechanisms from academia, which addressing requirements of the reliability with real time for perfecting industrial process automation.

The article discuss too the problems of sensor networks and the data of the wireless network signals that have not to be addressed until this time in order to use the wireless technologies in control networks and industrial surveillance which may normally contains thousands of sensors and controllers.

In order to carry outs the wireless controller systems assigned tasks, it is essential for distributing sensing and control devices and subsequently actuation for applying more modern strategies where supports new synergies the interconnection of individual systems.

Wireless technologies with perfect advantages allows to reduce bulk and installation costs, and also can modifications of the network architecture by adding or reorganize the nodes easily implemented without disadvantages costs of wiring with high scalability of increasing the wireless sensor and using helped algorithms (e.g., for vibration monitoring applications) to raise the level of performance for the system [19].

(S. Cai, M. Becherif, M. Wack, M.Y. Ayad and A. Kebairi) suggested in their paper, a wireless adaptive PID-Fuzzy Logic device for controling the angular displacement of an automobile Pierburg mechatronic actuator and improve a wireless network control.

The proposed PID-fuzzy logic topology through it's worked principles depends on the traditional PID controller and the fuzzy mathematical logic technique which can make the angular displacement precision more beter and can reduce the time delay in the wireless communication through the control loop.

The PID controller cannot achievement a good control in the highly nonlinear and uncertain control system. Therefore, in case of combaining between the advantages of FLC (Fuzzy control technique) with the traditional PID controller, the optimal FLC-PID controller can be designing.

It is known that Fuzzy control technique is a computer intelligent control dependes on the logic fuzzy dialestics, fuzzy collection principles and fuzzy lingual variables in add to has nice properties with the traditional control systems that can be explained in two advantages:

1) There is no needing to knowing the model of system.

2) The controller is powerful to deals with the variance in parameters .

The imperfect of this technique, is the difficult to overcome the steady-state error, while the classical PID controller has perfect performance due to its reliability, simplicity and the high steady-state of it.

Hence, the PID-fuzzy logic controller will be apropriate for the wireless control of the mechanical Pierburg actuator.

The authors proposed design PID-FLC for a wireless control by adding WLAN wireless communication into the system in which the derivative gain with adding of the second input for the FLC, which can provide for the theory of the system the derivation effect.

The suggested PID-FLC can be looked as a controller with mixed properties for FLC and PID controller.

The block diagram of PID Fuzzy Logic wireless networked Controller which is proposed in order to wireless control of the mechanical Pierburg actuator, can be shown in figure 2.5 [20].

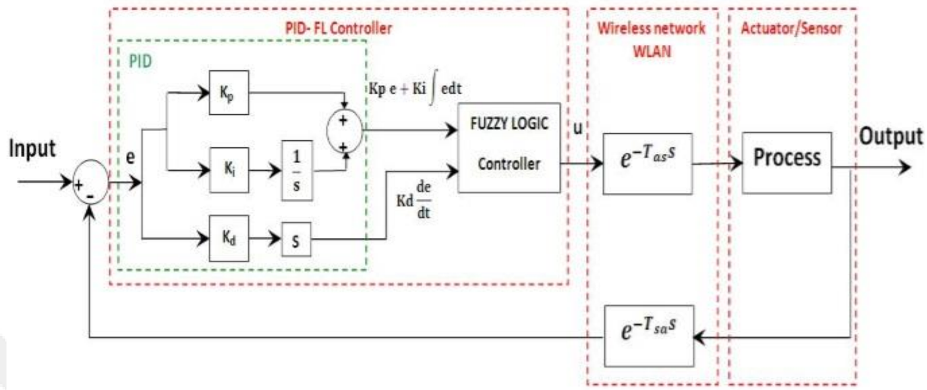

Figure 2.5: Block Diagram of PID Fuzzy Logic Wireless Networked Controller [20]

The authors (Terry Blevins, Mark Nixon, and Willy Wojszni) highlighted in their paper on the wireless PID controller which known as (PIDPlus), where the algorithm of the proposed device is depending on rate computation in order to caculate the updates for non-periodic measurements and adjustment of the PID reset by assuming and estimte a new theory to account for non-periodic measurements for PID control.

this measurements based on Kalman filter superintendent which was adjusted to use with a these wireless measurement, while it will be shows the way of modifying the Smith Predictor to be suitable with non-periodic wireless measurement.

The suggested device (PLUSPID) may can supplying the same control quality which can be provide with wired PID, although interruptions of signals and slow updates for wireless measurement.

The suggested combining idea will deals with feedback control by using a wireless transmitter. For compensate for the slow, non-periodic and unreliable communications, will be provide an information to explain the Smith Predictor where the way for transaction with the updates of non-periodic measurement necessery in case of implementing of closed loop control with wireless transmitters [21].

2.1.3 Studies Interested in the Parameters of Controller

This section highlight a number of studies that have been concerned with calibration of general three parameters (proportional, integral and derivative) of PID controller.

Especially, those three parameters are highly sensitive with the process variables in which the controller is used to reach optimum performance.

The author (Adnan Aldemir) investigated the proportional-integral-derivative (PID) controller behavior which was tuned depending on phase margin.

The effect of the error code force for control with experiments of wireless temperature control is investigated by the three general terms tuning parameters (proportional, integral and derivative) of the PID controller which are calculated generally by non-parametric ways.

Based on a MATLAB/SISO tool (Control System Designer tool), the parameters for control were estimated in order to adjust input–single output controllers depending on the diagram of root locus (RL).

In the experiment, along of 300 seconds and on the fixed heater capacity (10%), a primary value of steady state was obtained for calculate the system bias values.

The results confirm the wireless temperature control successfully performance wanted set values that selected the group of different points based on using control for the robust error with adjusted parameters.

The study goal was to build a wireless PID controller with diagram of RL which determined the integral square error (ISE) and the integral absolute error (IAE) values with achieve the properties on the phase margin in order to perform the experiments for wireless temperature control with using MATLAB/Simulink and algorithm of PID control on-line is used for group of the different points [22].

The authors (Jinwook Kim, Pyung-Hun Chang and Maolin Jin) designed proportional-integral-derivative (PID) controller which depending on the Fuzzy principles by using the time-delay estimation (TDE) by adjust the parameters of suggested controller by utilizing the TDC on the assumption that the fuzzy PID controller is a comprehensive package for time-delay controller (TDC) during a discrete-time domain.

Additionally, the fuzzy PID controller performance can be better by employing the non-linear control surface which was presented with the different fuzzy parameters, so a fuzzy TDC is proposed by utilizing the time-delay estimation (TDE) with the needed fuzzy error dynamics, in order to convert the formula to the fuzzy PID controller from the fuzzy TDC in a discrete-time domain.

To get a fuzzy control output singleton fuzzifier, have been use the MIN operator with the AND operation and center average defuzzifier, in add to check the discrete and continuous outputs of the PID controllers in order to derive the discrete fuzzy PID controller output.

By employing the time-delay controller (TDC), the initial parameters for the discrete fuzzy PID controller was determined, where the TDC uses the delayed information during time for the control input and state variables to estimate outer disturbances and anonymous dynamics directly.

The fuzzy PID controller is connected to the fuzzy TDC and TDC because of the relationship between different control concepts through the equality situations in a discrete-time domain, will helping to tune the parameters of fuzzy PID controller systematically [23].

The authors (Cheng ZHAO & Lei GUO) from their paper tried to present a theory of PID controller has the ability to deals with uncertain nonlinear systems, by build a 3-dimensional manifold which can through it chose the three PID parameters randomly to achieve stabilize in most of uncertain and nonlinear dynamical second order systems by a simple and easy method for design the PID parameters with a mathematic confirm of the approximate adjustment and universal stability for the closed-loop control systems.

Furthermore, the famous Newton's second law in mechanics yet plays a basic part in the modeling of dynamical systems (that can be tuned employing the PID controller) for the physical world.

So they tried to build some enough and needful requirements and calibrate the gains of feedback for the smallest possible value during investigating of the necessary manifold which help to select the parameters of PID to achieve the optimal stabilization of nonlinear uncertain systems, and also they followed a theoretical framework similar for which using in fundamental PID controller in order to the investigation of the maximum capability of the feedback mechanism [24].

While the authors (Ibtissem Chiha Noureddine Liouane and Pierre Borne) by their paper using the multi objective ant colony optimization (ACO) by decreasing the multiobjective function (which is distinguished by its ability to identify the Pareto optimal solution) for calibrating the three parameters (Kp, Ki, and Kd) of PID controllers.

(ACO) is a heuristic approach developed latterly with the aim of finding solution for the strenuous combinatorial optimization problems.

Depending on its ability for adaptive which allows the possibility be employed to different optimization problems additionally various versions for the same troubles.

The suggested PID controller can be shown in figure 2.6 [25].

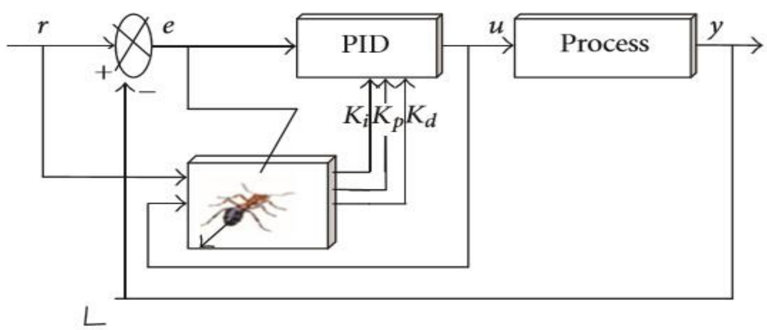

Figure 2.6: Proposed PID controller based on ACO [25]

The fifth study in this section for authors (L. F. Recalde R. Katebi and P. Katebi) in which they suggested calibrated method for PID parameters that can bypassing the imperfects of transmitted information from sensors or during transfer its outputs over a communication network which cause the difficulty of tuning the three parameters for PID controller due to the random delays entered in the feedback loop by the network.

The design method depends on polytopic description of the system, that can be provided employed a pdf principles for the delay distribution.

The design of suggested controller presented is undergo on assuming of the system is continuous with delayed inputs and the sensors for the system are time-driven while the actuators and controller are event-driven where different sampling rates and modulation conditions are not included.

In this design method there is needing of perfect performance for both network and system

Additionally, instable in the NCS (Networked Control System) because of the density for traffic where the design of proposed PID controller is depending on expect for the possible delay that occur with a models group which base on a parameter of tuning [26].

2.2 WIRELESS AND PID CONTROLLER

This section will cover the important imperfections of the wireless networks that effect on the PID performance after that will cover some operation concepts of wireless PID controller.

2.2.1 Wireless Networks

Despite the great development of wireless communications field and ıt reaches to a very high level of idealism, but it is not free of imperfects that have not been exceeded so far despite the great efforts in this area, which negatively affects the performance of the components of this wireless network, and may be the most important of those Components are controllers.

2.2.1.1 Wireless networks imperfections

The varying delay is drawback most apparent likely for happen with using of the wireless network, and because of the random nature of medium induced delays, the intervals of transmitted data packages to the PID controller be irregular.

In other side, there’s some studies aims to decreases the fades and distortion for frequency effects with an unsuitable cases by showing proposed framework for the turbo equalization with process of the iterative decoding, that depending on channel equalization implementation during double decision feedback equalizer (DDFE) which was designed by employing noncomplex least mean square algorithm (LMS). In this section, it will be highlighted on the wireless network disadvantages and the used methods to overcome it [27].

Delay Time

The time delay in the wireless communication networks may be happen between the controller and sensors or between the controller and the actuators, where this delay may be randomly, can be described with its upper limits or can be determined online [28].

At present, the congestion and bottleneck in Wireless Networks happen because of the losing in the packet of data, while the greater defeat of AODV (Ad Hoc On-Demand Distance Vector) routing protocol which is utilized in ad-hoc wireless network is a time delays [29].

One of the important factors that effect on the performance of wireless network is a delay, and much studies discusses the measurement and analysis of the time delays.

And the figure 2.7 shows the randomness for the delay time for Wireless Sensor Network, while the various nodes time delays is change during big area [30].

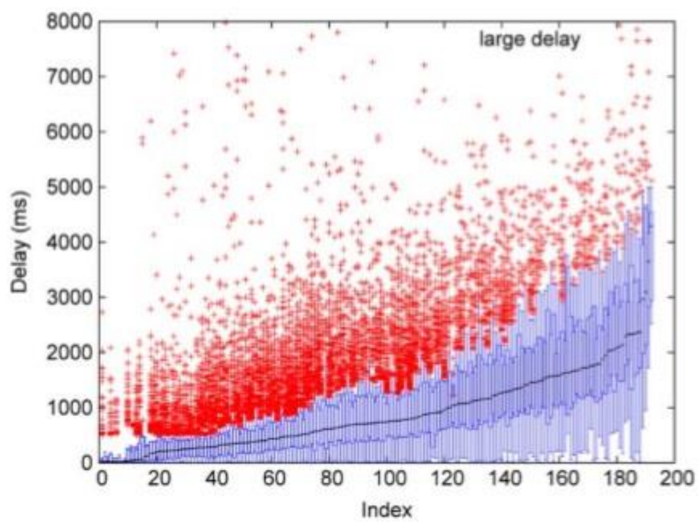

Figure 2.7: Delay distribution for all nodes [30]

Where the channel coding and data encryption are very important factors in wireless sensor networks, in order to implement secure and powerful communication [31]**.** In order to improve the using of movement control, home robotization, and so on, remote Wireless Sensor Networks, which are known in term of (WSNs) was created [32].

- **Network access delay**: The time it takes for the network to be available to accept the data.
- **Frame time delay:** The time for the transmitter to place a packet on the network.
- **Transmission delay:** The time the packet spends within the network.

Where the overhead on the networks, packet sizes of data and the channels bandwidth effect on the values of these time delays [2].

Many of theories tried to solve the time delays imperfects, such as discrete-time control theory, but it can't be applying if the time delay is big comparing with the main the control loop time constants [26].

Packet Loss

In the networks (until digital networks) the packet loss is normal phenomenon usually, but in spite of all network protocols, this loss will leads to deteriorate in the performance of the network, so, many methods have been suggested to deals with this disadvantage [26].

Power consumption

The power consumption economy of the wireless devices from the important aims of the manufacture companies, for example, in the wireless sensor network the power consumption in its nodes can be classified into three parts, power consumption in sensor (through sampling of the work environment and through converting operation the data from analog to digital (ADC), power consumption in the processing unit (through managing the sensor, processing operation of the data, communication protocol and other related tasks) and the power consumption equipment (through the receiving and data transfer operations) , where the power consumption into these three parts can be obtain in figure 2.8 [33].

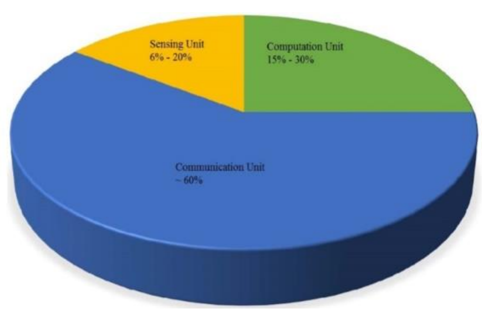

Figure 2.8: Power consumption into sensor, processor and communication equipment [34]

Into networks of power distribution, the importance of the active operation and designing for power distribution systems became have big importance in the renewable energy choices integration, where staying the measured voltages under suitable ranges is animate; therefore, control units are employed in the systems of power distribution [34].

2.2.1.2 Networks solutions theories

Time Delay Models

There's many theories to overcoming the time delays troubles and bellow three delay models have been described:

- **Gaussian Distributed Random Delay**: This theory aims to represent the different random access protocols, by delay model which choose the variance by investigating the network attitude.
- **Partially Random Correlated Delay:** the basic idea of this model is capture the delay parameters by the positive correlation between the arriving times for the consecutive packets where the uniformly distributed delay is paired with the past value
- **Constant Delay:** Which based on the determining a value and employing it as assumed constant delay, which (this model) can be used only through deterministic cases, in which considering that safety slots is reducing the performance because the control delay will be very long [2].

Packet Loss Models

- **Compensation of delays and packet loss by model predictive control:**

  This models determine in each step of the time a sequence for next control inputs to compensate the loss in the packet and the delays of time which happen in the communication network.

- **Compensation of delays and packet loss by means of virtual control inputs:**
  This model focusing on the input sequences that stored in order to compensate the loss in the packet and the delays of time between the controller and the active actuators in the industrial network.

- **State estimation as part of control-communication co-design:**
  While this model aimed to rebuilt the processes state even in case of losing in the packets which be happened among the wireless controller and sensor and the controller and adds this estimate with a controller which be implemented by wireless transmissions [26].

2.3 NETWORKED WIRELESS PID CONTROLLER

The wireless control systems are become available every industrial processes absolutely in order to implement of feedback loops principles frequently for reaching the ideal performance based on wireless advantages which facilitate the expansion the processes areas of automatic control with changing in measured values that can be transmitted to the wireless control device from every place immediately [26].

2.3.1 Networked Control Systems Theory

The information links and how often information has to be communicated and fast of transmitting from the necessary factors to reach the perfect performance of the wireless control networks. Therefore, its important incorporate the good advantages for the communication network with the plant model.

Classifications of the incorporate methods of the communication network the closed-loop systems or with the plant model as follows:

- **Control-theoretic approaches:** the time delays of data transfer over network must be attended to it the time of designing the controller and analyzing the total system which consider the data transmission and the control parameters, where the information feedback is important in order to attenuating the disturbances.
- **Information-theoretic approaches:** Which deals with the state of the universe of data transfer with one bit-rate is not enough for the control implementation of a certain process.
- **Network-theoretic approaches:** The communication topology may change during the time in case of transfer data between the nodes because of the lost in data packets or creating or disappearing links of the communication process.

The network-theoretic approaches is used to solve the problems of packets lose but there are many problems have been to be solved, where the controller cannot predict the plant processes in future only in the case of providing the information from the actuator [26].

2.3.2 Tuning Theories of PID Controller

The tuning of the general parameters (Kp, Ki and Kd) of PID controller together by using the popular methods not adequate in some times, therefore, the truth that indicates derivative action increases stability is contradicts the belief that increasing the derivative gain may be lead the system to be unstable.

Additionally, the generalizations that says derivative gain of the PID have switched off in the industrial fields represents the misunderstandings for these parameters and its importance.

So, many theories have been proposed for tuning the three parameters of the PID which considers mitigation the load disturbances with (Stability and stability) as two importance aims must to reach those [2].

In this section it will highlighting on three methods for parameters tuning:

2.3.2.1 Ziegler-nichols (Z-N) method

It is one of the oldest attempts for tuning of PID controller, where the process is approximated firstly employing a first-order lag plus time delay process as shown in equation 2.1:

$$P_{\mathrm{LPD}}(s) = \frac{\propto}{sL} e^{-sL} \tag{2.1}$$

The PID parameters are determined by using analytical terms which depends on the approximated $\propto$ and L values, while second Ziegler-Nichols (Z-N) method is to set the system under the basic amount of the proportional control then the gain will be increase until reaching the case periodic oscillations of the system and this gain leads to the knowing the ideal values of other tuning parameters by using easy mathematical equations.

But in some processes, this criterion leads to unsuitable in the values of gain margins and phase, therefore the system will be unstable and much sensitive to divergences of parameter [2]

Modern proposed method to tune the PID controller parameters depends on the relay feedback way which is adjusted by enter a constant phase transfer function under the random big domain of frequencies in order to ununificate all ways of tuning that same Ziegler–Nichols method (Z-N) based on allowing for calibrate the parameters of PID controller depending on relay feedback without the final frequency for class of processes [35].

Another modern study tried to chain this method with other, such as highlighted on using the Chien-Hrones Reswick technique in order to modifying the oldest theory for tuning method which is (Ziegler-Nichols) to get the suitable parameters values of the PID controller that controlling the speed of the DC motor.

This technique requires a stable system with step input S-ship curve which are depending on open-loop step response enrollment for the DC motor, that can be describe by contains much of parameters such as inductance (L),time (T),constants (K), and armature (a) which can be calculated from the process unit step response, and the maximum point of step response slope at first determined, while the coordinate axes and tangent will evaluate the values of the parameter (a) with parameter (L) and the intersections of the tangent line with the time axis and line y(t) will provide the constant amount for the time (T) [36].

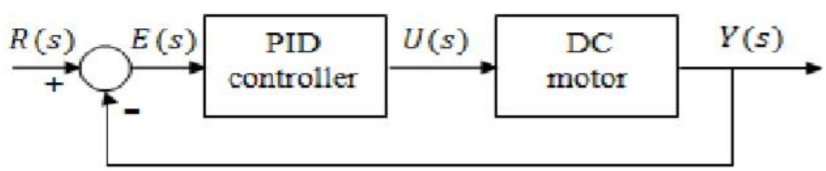

Figure 2.9: The block diagram of DC motor control system [36]

On other side, some studies compared between this method and another, such as study that discussed the possibility of automatically tuning the parameters of PID controller based on the genetic algorithms for closed loop systems to achieve the suitable performance for all plants.

This approach will search to get the desired gains of three parameters (Kp, Ki and Kd) to neglect or reduce the error between the measured values and desired response for the process.

Where the figure 2.10 compares the different between the response by using the genetic algorithm and by using (Ziegler-Nichols) method [37].

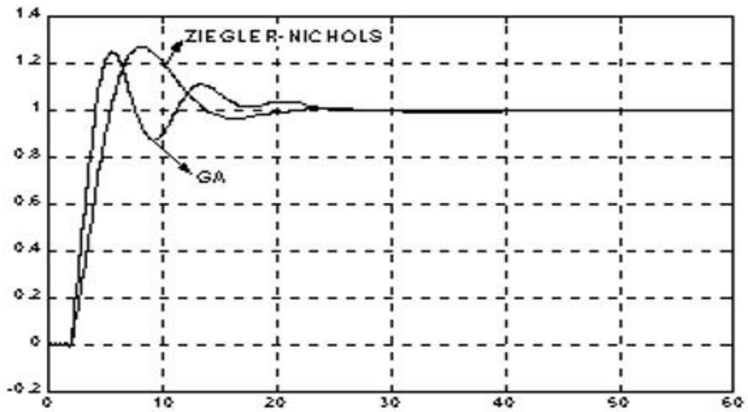

Figure 2.10: Closed-loop step response [37]

2.3.2.2 Phase and gain margin methods

Its approach similar to (pole placement) theory which based on the approximation where the equation of the closed loop for the system is derived if there is low order process which achieve the gains of PID controller like free parameters, in PM and GM principles are depends on achieve margin constraints.

Gain margin (Am) is determined by using the equation (2.2):

$$A_M = \frac{1}{|\ C(jW_{PC})P(jW_{PC})\,|} \tag{2.2}$$

While phase margin can be calculated as equation (2.3):

$$\phi_M = arg[C(jW_{gc})P(jW_{gc})] + \pi \tag{2.3}$$

Where:

W_{PC} = phase crossover frequencies.

W_{gc} = gain crossover frequencies [2].

Some modern studies tried to develop the principles of this theory to bypassing time delays, such as present a graphical calibrating way of PID controller for second order systems by employing dominant pole placement idea (where a conjugate poles pair is selected in order to achieve the suitable time response for the closed loop systems) with ensured phase margin (PM) and gain margin (GM) where the borders of constant values of PM and GM were obtained based on gain phase margin tester and the method of stability equation, while the limited area of GM and PM contains the values of PID controller parameters which have been obtained graphically [38].

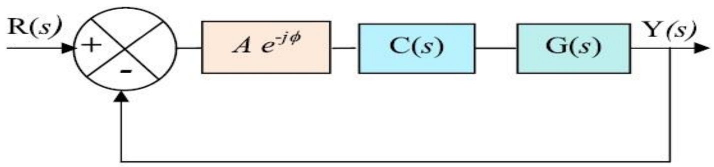

Figure 2.11: Block diagram of a general feedback control system with GPMT. GPMT is a Computational aid often used in the simulation to define the GM and PM Boundaries

2.3.2.3 Migo and amigo methods

The tuning by MIGO method based on simulating many processes and find the mutual analytical relationship between them.

$$P_{KLT}(s) = \frac{Kp}{1+sT} e^{-sL} \quad (2.4)$$

Where:

K_p = The static gain.

T = The time-constant.

L = The time-delay [35].

The robustness criteria making the Nyquist curve of the loop transfer function outside the known circle in order to calibrate MIGO controller by the values of center in (c_R) and radius (r_R) that can be calculated by the equations (2.5) and (2.6):

$$c_R = \frac{2M^2-2M+1}{2M\,(M-1)} \quad (2.5)$$

$$r_{\mathrm{R}} = \frac{2M-1}{2M\ (M-1)} \tag{2.6}$$

Where:

M = The parameter by which the robustness is captured.

When using this method is noted there is no perfect rules for parameters tuning can depends on KLT plants, when analyze the effects for various plants parameters, therefor, the AMIGO theory may be more conservative less performance [2] .

2.3.2.4 Optimization based method

This methods based on defining the cost function which are built of a mixture of the design criteria and with consider the constraint of stability, the cost function will be minimized.

But the imperfect of this theory is the local minima is existed, that leads to stop the optimization process before achieve the needed results.

From a pool of individuals, the fitness of each one is graded using a cost function, and fittest ones are chosen. The pool is repopulated using probabilistic methods based on the chosen individuals. These process is repeated until the design requirements are met. In optimization based methods, the design requirements must be carefully evaluated. Overlooking a constraint such as stability, or transient response may lead to futile outcomes [2].

Finally, in present much authors tried to propose optimal techniques for tuning the parameter of PID controller. For example, study based on elephant herding optimization (EHO) to get the perfect values of the PID controller device parameters to reduce the integral-square-error (ISE) (that have been obtained by employing the tables of beta and alpha), which happen in the response of unit step.

The unit step response in (ISE) represents the level of performance for proposed system, where this performance index needs for some values only of beta and alpha parameters [39].

Another study proposed auto-tuned IMC-PID controller in order to achieve the perfect control performance for a real-time which aims to present the suitable identifying of a linear model for the technique of Internal Model Control (IMC) under the conditions of dynamic equilibrium which fails usually in the various process dynamics for presenting occasion responses of nonlinear industrial processes. In this technique the constant time of the closed-loop (k) changes with the helpful which presenting from the fuzzy rule principle that is designed under the present conditions of the plant [40].

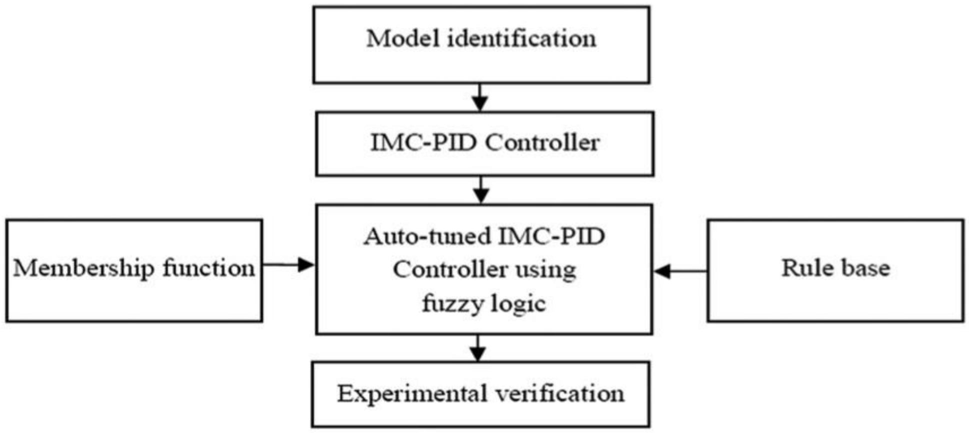

Figure 2.12: The flow chart of our proposed work [40]

Additionally, in another study, direct synthesis method have been used to design the PID controller for working under the time delays condition for the different shapes of the integrating systems implement the suitable performance in various processes.in this technique the desired characteristic equation have been compare with the proposed system which contain the filter with PID controller, while the parameters will be adjust by employing these desired equation which contain multiple poles are be limiting in the desired location in order to achieve the robust [41].

3. METHODOLOGY

The basic assuming is control process has always been executed on underlying periodic while a modern value is already available for every execution [21]. But the desired value may not be received in a circumstance where the process may be very important, because it's known the radical trouble of wireless communication is the mutual relationship of the request, ability and environment.

And although the basic changes in performance of technologies communication and it's theories have introduced the wireless networks and communications a novel age. Where the modern technologies like artificial intelligence, internet of things and big data work to reinforce an excitable development in the data traffic. But, the absence of an intact theoretical standards is still as a huge defiance that have to be solved [7].

So in order to minimize errors a wireless PID controller which was suggested, will decide appropriate action for reaching the optimal reactions.

In proposed control system, the process variable which is measuring by sensor will transmit to control room by outer wireless feedback and to microcontroller by inner wired feedback.

3.1 WIRELESS PID CONTROLLER THEORY

The proposed system consists two closed loop. The inner loop consists microcontroller (which will be PIC16F877A, that have 8K words x 14 bits of FLASH program memory) [42], sensor and the controlled plant (the process) as shown block in figure 3.1.

While the outer loop consist of RF link between the inner loop and the control room which will be far from the controlled plant (process), where transmitting the process variable (actual value) that’s measured by the sensor and receiving the desired value with the same actual value that will be pass together to the microcontroller [43], as shown figure 3.1:

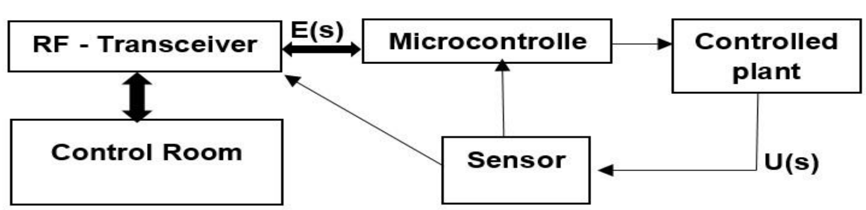

Figure 3.1: The proposal transmitter [43]

It clears from figures 3.1, that the microcontroller will receive processing variable from sensor and the desired value with same processed variable from the RF – transceiver.

On the other side the control room receives the processed variable (sensor reading) by it's "RF-transceiver" too [43], as shown in figure 3.2:

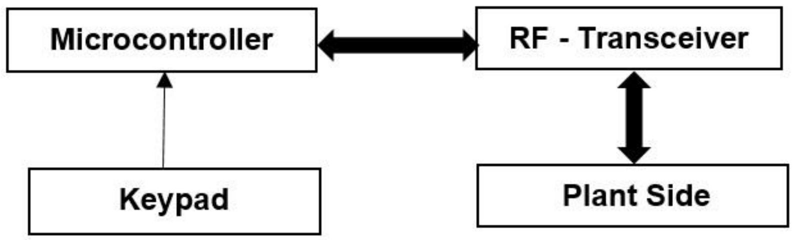

Figure 3.2: The proposed control room transmitter [43]

3.2 THE SIMULATON OF PROPOSED CIRCUIT

This section will explains the simulation of the proposed wireless PID controller on two sides.

3.2.1 The Control Room Circuit Simulation

In control room, the microcontroller will receive processing variable which was received by RF-transceiver (Bluetooth HC-05) and the desired value that entered by the user (KEYPAD – SMALLCALL).

The microcontroller will add them together by the using micro c language that uploaded on it.

3.2.2 The Plant Circuit Simulink

The microcontroller compares between the processed variable which was reading by the sensor and the same processed variable which was received by RF – transceiver to improve that the sending set point (desired point) which is the wanted set point to overcome the error which may be caused by wireless communication.

If the two values of processed variables were same then the microcontroller will apply the desired value. But when there's different between the two values of processing variable, then the microcontroller will works as smart controller so that it has the ability to decide the optimal reaction depending on last conditions of the controlled plant upon on the code which uploaded on it and which allowing the user to convert the working ranges as he propose.

In this case, smart controller will work on three possibilities where:

- It sets the heating degree on (65 deg.) if the final actual reading was more than (99 deg.).
- It sets the heating degree on (25 deg.) if the final actual reading was less than (10 deg.).
- It sets the heating degree on (45 deg.) if the final actual reading was between (10-99 deg.) [43].

3.3 EXPERIMENTAL SET UP

The operation of two circuits are depending on a PID Controller that is implemented on two microcontrollers and a sensor (ds18b20) which provides the two microcontrollers with the actual temperature degree, while every LCD displays the actual and desired degrees, as shown in figure 3.3:

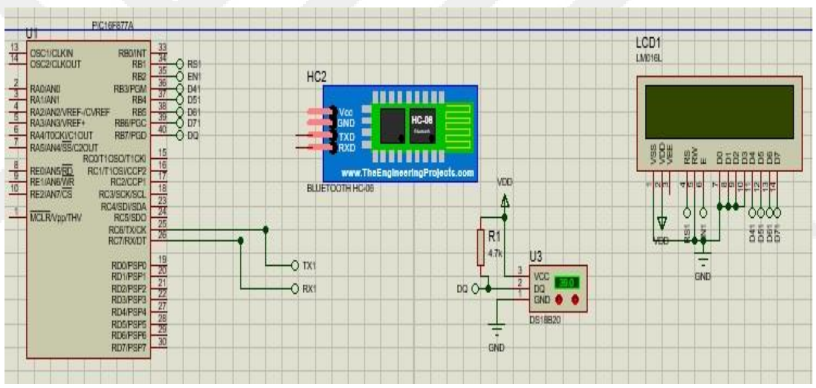

Figure 3.3: The Simulink of plant transmitter circuit [43]

For data transmission, Bluetooth was used, while the Keypad equipment will allow for user to enter the desired value as he propose [43], as shown in figure 3.4:

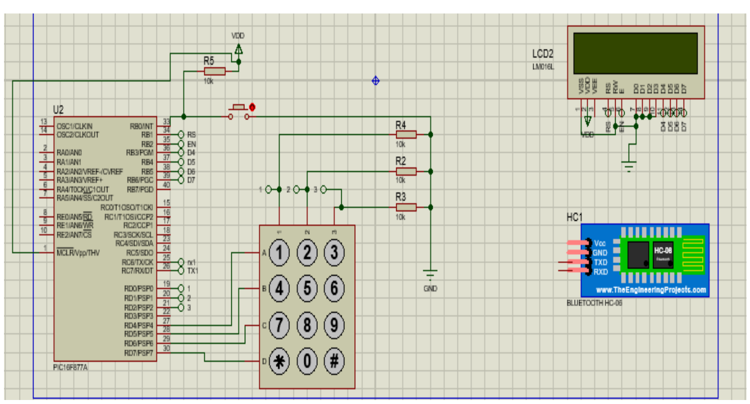

Figure 3.4: The Simulink of plant transmitter circuit [43]

An UART (Universal Asynchronous Receiver/Transmitter) used to make interfacing between the two microcontrollers.

3.4 SYSTEM DESIGN AND EQUATIONS

Controlling or monitoring temperature is important in much processes, because it's very critical and widely measured variable for many mechanical plants, therefore it is important parameter in control systems. In this chapter the test is carried out on a thermal system, the heater as example [44].

Assuming the Smart Wireless PID controls on heater as shown block diagram bellow, in figure 3.5 will be important to analyze and evaluate the system as a closed loop control system, where was used the Taylor Series Expansions of Exponential Function used to implement the Heater on Matlab/Simulink whereas a finite Taylor's series is an exponential or power function [45].

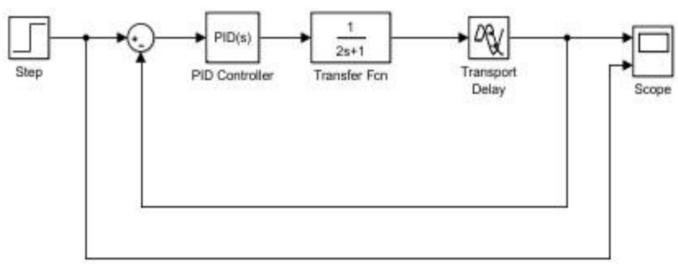

Figure 3.5: Matlab/Simulink plant circuit

A large number of the tuning methods are generally available for calibrate the parameters of controller. As well as, the tuning method selection is also considered as a huge constraint. These methods are basically depending upon the nature of systems which are exactly controlled in order to achieve the system transfer function firstly. The transfer function is able to be founded through using mathematical modeling for the systems [46].

This section will discuss a simple mathematical model for proposed system. The system that contains the heater which is deriving by Smart Wireless PID Controller will be simulated in order to regulate the heater temperature along with minimum settling time, peak time, rise time, overshoot and rise time.

3.4.3 The Heater's Mathematical Model

Transfer function of heater can be written, as equation 3.1:

$$T(s) = Ke^{-Ls}/(1+sT) \qquad (3.1)$$

Where:

L – Delay time.

T – Rise time [44].

And this equation will be applied as a Taylor Series Expansions of Exponential Functions in Matlab/Simulink and will be sitting on the values (L = 0.5, T=2).

3.4.4 The Mathematical Model of Controller

Between the methods which are using to design the parallel Proportional-Integral-Derivative controller is Ziegler-Nichols tuning rule.

The algorithm of transfer function for the standard PID is:

$$\text{U(t)}= Kpe(t)\frac{Kp}{Ti}\left[\int_0^t e^t dt + KpTd\left(\frac{de(t)}{dt}\right)\right] \qquad (3.2)$$

The PID controller equation in the S-domain is able to be written as:

$$\text{Us}= \text{Kp } [1+ \frac{1}{Ti.S} + \text{TD.s}] \text{ E(s)} \qquad (3.3)$$

And by applying Z-Transform on equation (3), the PID Controller Discreet Form can be written:

$$\text{U(z)} = \text{E(z) Kp } [1+ \frac{T}{Ti(1-z^{-1})} + Td\frac{(1-Z^{-1})}{T}] \qquad (3.4)$$

Then:

$$\frac{U(z)}{E(z)} = \text{Kp } [1+ \frac{T}{Ti(1-z^{-1})} + Td\frac{(1-Z^{-1})}{T}] \qquad (3.5)$$

After applying The Partial Equation Method equation (5) will be as equation (6):

$$\frac{U(z)}{E(z)} = a + \frac{b}{(1 - Z^{-1})} + C\,(1 - Z^{-1}) \qquad (3.6)$$

Where:

a = Kp

b = $\frac{Kp\,T}{Ti}$

c = $\frac{Kp\,Td}{T}$

[11].

The standard Block diagram for a continuous parallel (proportional, integral, derivative) PID controller as in figure (6) where Kp, Td and Ti are the proportional gain, derivative time constant, and the integral time constant in respectively [47]:

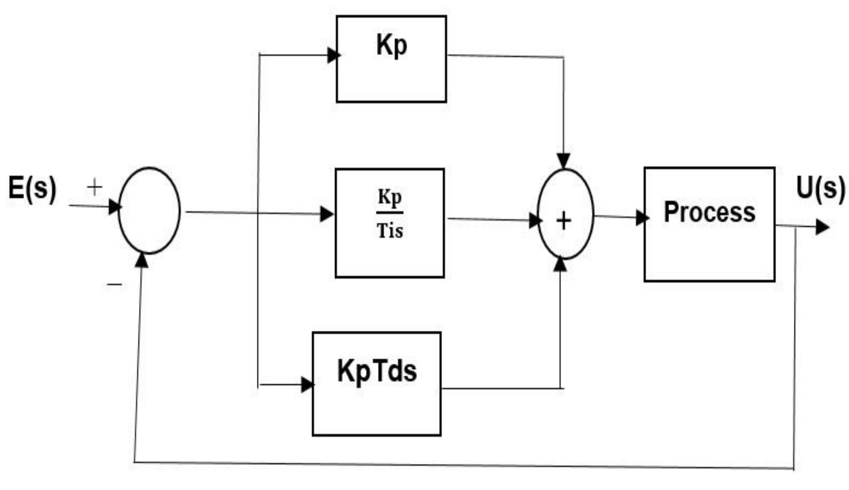

Figure 3.6: Standard block diagram of a continuous parallel (proportional, integral, derivative) PID controller [47]

4. RESULTS

In this chapter, the results of Matlab/Simulink experiments will be explain.

4.1 THE EXPERIMENTS AND RESULTS

The system that was showed in figure 3.5 represents the Simulink system in the experiment, while the values of PID parameters will be tune in this section.

It will be consider the below assumed values for the PID parameters and the system response at these values [43], rise time and other things will evaluated as coming experiments:

4.1.4 First Experiment:

Table 4.1: Assumed PID controller parameters [43]

Kp	Ki	Kd	N
0.721	1.923	0.122	50

When applying values which is shown in table 4.1 on Matlab/Simulink, figure 4.1 will be gets:

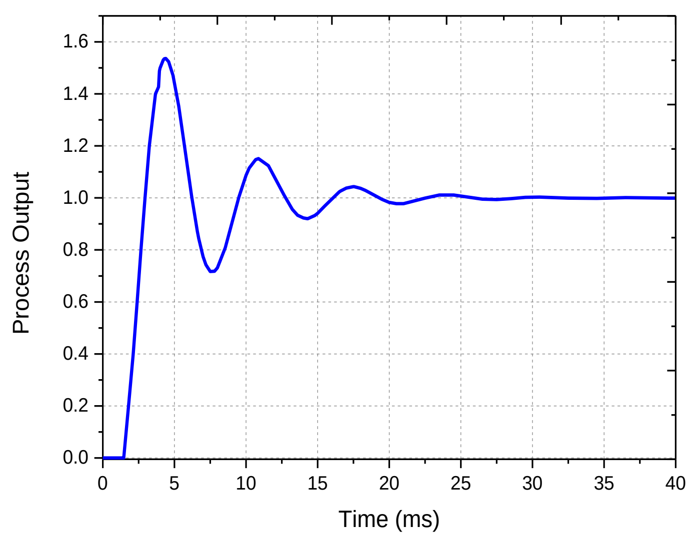

Figure 4.1: Scope for PID controller parameter in table (4.1) [43]

While, the table 4.2 will explain the values of response at the time in (ms):

Table 4.2: the values of response for first experiment [43]

Time (ms)	Res. Value
1.463	0
1.796	0.2
2.119	0.4
2.397	0.6
2.665	0.8
2.950	1
3.888	1.427
3.999	1.499
4.600	1.524
4.900	1.472
5.700	1.202
6.200	1.006
6.599	0.872
7.000	0.774
7.500	0.717

The value of times and overshoot for the first experiment is shown below:

Delay time = 1.38 (ms)

Rising time = 0.12 (ms)

Peak time = 4.39 (ms)

Peak value = 1.53

Steeling time = 21.40 (ms)

Overshoot = 0.53

4.1.5 Second Experiment:

Table 4.3: Assumed PID controller parameters [43]

Kp	Ki	Kd	N
1.122	1.523	0.327	100

When applying values which is shown in table 4.3 on Matlab/Simulink, figure 4.2 will be gets:

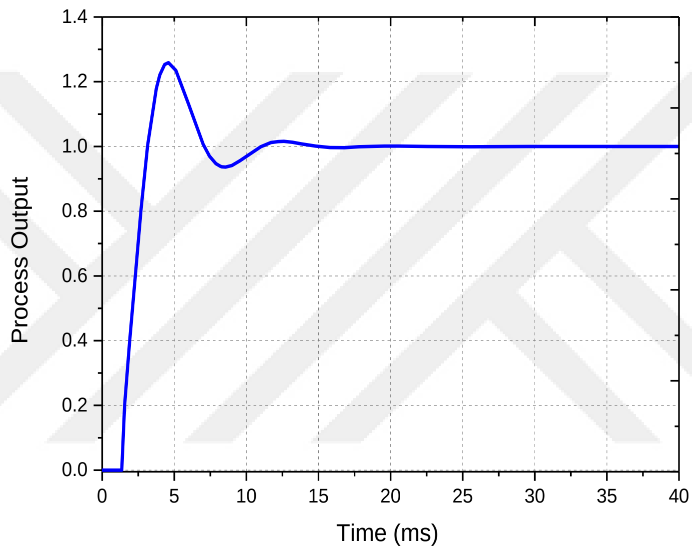

Figure 4.2: Scope for PID controller parameter in table (4.3) [43]

While, the table 4.4 will explain the values of response at the time in (ms):

Table 4.4: Response values of second experiment [43]

Time (ms)	Res. Value
0.000	0.000
1.355	0.000
1.559	0.200
1.900	0.3950
2.300	0.6022
2.700	0.807
3.152	1.004
3.755	1.179
5.111	1.235
5.999	1.130
6.999	1.007
7.444	0.9700
8.555	0.9361

The value of times and overshoot for the second experiment is shown below:

Delay time = 1.40 (ms)

Rising time = 1.49 (ms)

Peak time = 4.95 (ms)

Peak value = 1.25

Steeling time = 14.35 (ms)

Overshoot = 0.25

4.2.3 Third Experiment:

Table 4.5: Assumed PID controller parameters [43]

Kp	Ki	Kd	N
1.648	1.074	0.1168	1.267

When applying values which is shown in table 4.5 on Matlab/Simulink, figure 4.3 will be gets:

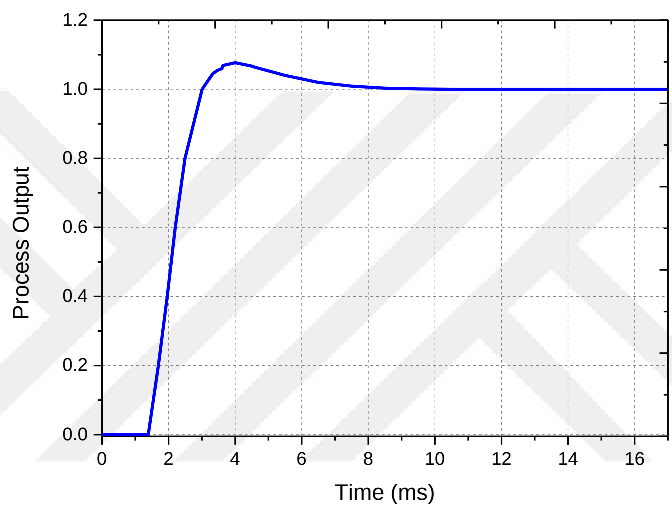

Figure 4.3: Scope for PID controller parameter in table (4.5) [43]

While, the table 4.6 will explain the values of response at the time in (ms):

Table 4.6: Response values of second experiment [43]

Time (ms)	Res. Value
0.000	0.00
1	0
1.300	0
1.695	0.2
1.961	0.4
2.200	0.6
2.494	0.8
3.009	1
3.222	1.03
3.330	1.045
3.444	1.053
3.633	1.059
4.000	1.077
4.590	1.064
5.500	1.040
6.500	1.020
7.500	1.009

The value of times and overshoot for the third experiment is shown below:

Delay time = 1.38 (ms)

Rising time = 1.21 (ms)

Peak time = 3.95 (ms)

Peak value = 1.07

Steeling time = 7.79 (ms)

Overshoot = 0.07

4.2 COMPARISSION WITH OTHER STUDIES

It's obviously the previous studies that addressed the wireless PID controller, tried for using different equipment to achieve fundamental logic of three terms for PID controller, which are (proportional, integrated and derivatives), developing the algorithms in order to reach the perfect principles of PID controller unit, focusing on the imperfects of wireless networks such as delay time and the dropout of transmitted data and calibration of general three parameters for PID controller, which are highly sensitive with the process variables in which the controller is used to reach optimum performance.

The proposed idea tried to companies between basic mathematical principle (the comparing) and the properties of programmable microcontroller which showed the device ability to bypassing the wireless signals imperfections, such as packet loss and time delays especially.

In the proposed device, feedback will provides the measured values of requiring operation to implement the comparing principle between the received data and measured data without any effect on the parameters values which was be calculated by the (Z-N) theory or other, while other studies tried to improve the gains of parameters for accessing to perfect performance.

Generally, the PID controller staying on fixed performance under case of loss or cutting packet or time delays, and will still on these fixed value unless repair the problem. While in case of proposed unit, the wireless PID controller will operates under the ranges that have been identified by the user, under case of loss or cutting packet or time delays, which gives the operation more flexibility for less the performance troubles under undesired cases [43].

5. DISCUSSION

Because of the PID controller device in its two types wired or wireless, is one of the most widely used control devices, specialists have made great efforts to develop it, in order to use in the field of industry, technology fields and other fields and applications.

The efforts included attempts to overcome the wireless defects of the device, and these efforts have been able to overcome some defects and was able to reduce the effects of other defects even if you cannot completely overcome them.

Even the old theories for tuning PID controller parameters, the belief became that it's Inappropriateness to the requirements of the times more prevalent, much studies to improvement them are appeared or replacing them with other be better and more effective with the requirements of present age at least.

The idea which is proposed in chapter three tried to combines between mathematical basic principle (comparing) and the ability of programmable microcontroller that is used in the Simulink experiment.

The Simulink for two circuits operation (control room circuit and plant side) explains the good ability to bypassing the troubles that may happen because of the wireless signals imperfections, such as packet loss and time delays especially.

The wireless equipment which is used in the experiment didn’t support the long distance, because the basic aim of it was secure arriving the data between two sides. Which can be replace with other equipment supports data transfer under long distance.

The idea focuses on design side of the wireless PID controller without focuses on the communication side for the signals transfer and trying in order to improve it.

In the design, the feedback that coming from sensor will provides the measured values of requiring operation to implement the comparing principle between the received data and measured data without any effect on the parameters values which was be calculated by the (Z-N) theory or other.

The program that have been uploaded on the microcontroller, gives the user the ability to convert the operation ranges as he suggesting

6. CONCLUSION

The packet loss and the time delays for the transmitted data is regarding as a big challenge and needs to be solved. Those two imperfections effecting directly on the wireless PID device through the effecting on the three parameters or through no access a last updating of the desired values which leads to unsuitable actions of the device.

Additionally, dominance of some false concepts in the industrial side leads to unsuitable actions of the device, such as, the concept that say the increasing in gain (kp) will increase the control system speed to reach the steady state generally, while scientific application confirms that with the too large increasing in (Kp), the system will begin in unstable state or may even oscillate out of control, with the fact that increasing reduces the settling time, and the increasing in (kd) leads to decreasing the overshoot and settling time, while using (ki) leads to minimize the steady state error.

A device may helping to indicate if there’s problem or cutting in the coming signal from the control room as emergency device.

It seems that PID controller will be smarter and will stay the dominant of process industry control.

6.1 FUTURE WORK

Dealing with suggested PID controller, has been carefully studied and discussed. Nonetheless, some improvements not tested arise here:

- The proposed wireless PID controller, can be employing as Smart controller in order to be used in the industrial applications after improve its communication equipment which can supports more long distance which reaches hundreds of meters.
- This Smart controller may can be used in the industrial applications after develop its program which can meet other industrial needs such as changing for operation ranges, indicating if there’s losing or cutting in the received signal from the control room or can be used as emergency device if there’s no feeding from sensor.

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