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Use of PID to increase the productive yielding of industrial equipment and machines of an electronics industry of Mexicali, Baja California, Mexico

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Abstract

The operational yielding of industrial equipment and machinery is a very important factor in the activities of each industry, because is part of productivity and quality indices of manufactured products. The majorly of this type of industries use widely a variety devices such as PID (Proportional-Integral-Derivative), which generates control of a diverse industrial operations, depending is required. The PID is designed at low cost with basic electronic components of low power as coils, capacitors, resistors, relays, and transistors, where some companies in the Mexicali city not use this type of devices and not have an optimal control in the manufacturing areas. An industry of electronic sector and that fabricates cell phones, tablets and laptops located in this city, reflected some problematic situations in where wasn't control in some industrial operations, and were occurred a lot failures and human errors an investigation to regulate these specific operations was made using PID. This scientific study showed the necessity of use this electronic devices and, when was applied its, was elaborated the control was observed an increase in levels of productivity and quality, and decreasing the costs by the presence of defective products without finished and stored in zones of manufacturing areas, delaying the process and the delivery to others areas and customers, and originating loss of customers. Other important aspect observed with the use of PID, was that equipment and machinery increased its life time generating low indices of electrical failures, because it's operated in the time required and not always were working even without raw materials to manufacture the products of the electronic industry evaluated. The investigation was made from 2017 to 2018.

Keywords: Manufacturing, electronic industry, PID devices, productivity, quality.

Introduction

The electronic industry is one of the very important sectors in the economy of each country, where globally, manufacturing a great diversity of products used in daily life and generates large profits in the millions when controlled industrial processes are carried out. In this type of industry, there are activities that perform functions in a very fast way and if there is not adequate control of industrial operations, it causes a large number of defects that cause economic losses and sometimes loss of customers to receive their products late **[1].** Industrial operations require optimal control to carry out their activities and, as they have specialized processes at high speed, electronic devices are required to generate this control and a fluid process is obtained, reducing the index of defective products that are of great concern to the personnel of management and supervision. That is why this study was carried out with the use of PID, preparing as a first stage a simulation in the MatLab program with diagrams and mathematical functions that represent control operations of industrial processes and in the second stage the design and development of electronic circuits They were adapted with industrial equipment and machinery and in manual activities, preparing actions to compare standardized and constant values with real values obtained from industrial processes **[2]**. This action is called feedback, in any type of PID control, be it proportional, integral or derivative. They are specialized mathematical functions, and have the objective of simulated way of evaluating possible scenarios of manufacturing activities, to determine the operating capacity of industrial equipment and machines and the human factor required in the production processes of the evaluated company. As Mexicali is located, in the state of Baja California in a region of northwestern Mexico and which borders the state of California of the United States, which is an area of this country with great consumerism and is where a large quantity is marketed of articles manufactured in the electronic industry of this city as the three mentioned, it is required of industries that manufacture their products quickly and efficiently **[3].**

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Use of PID in Industrial Manufacturing

This type of electronic devices are very useful in the electronic industry, because they have the ability to activate and deactivate high-power actuators such as fans, oil and water pumps, motors and other high-power systems, which are components of equipment. and industrial machinery, so that they operate at times when they are required and are not constantly switched on, generating an expense of electricity that is very high in Mexicali, mainly in the industrial price and with great power, thereby raising production costs [4]. There are other types of control devices that contain capacitors, coils and low-power resistors, and they do not work together as a PID, only they do not perform optimally, because the capacitors and coils have a delay effect on their operation and even when the device is inactive, they continue to operate and generate electricity consumption that is recorded in the electricity payment receipts. Table 1 illustrates an evaluation of the use of PID related to the operation of certain high-power actuators used in industrial processes of the evaluated company**. (Table 1)**

Table 1 shows the percentage levels of factors of importance in the

Table 1. Percentage evaluation of PID operation with actuators.

Factors	Capacity	Operation	Velocity
Actuators			
Fan	90	85	85
Water pump	85	80	80
Oil pump	80	75	80
High power spotlight	90	85	NA
Motor	80	80	80
Dry	85	80	85
Source Investigation analysis of literature and experts			

operability of the evaluated actuators, where it was observed based on analysis of operating times, periods without failures that generated operating stoppages, the need for corrective, preventive and predictive maintenance and quantity of manufactured products; obtain information on percentages of capacity, speed operation. Fans are used in the production process to keep the motors of a conveyor belt at a certain temperature to prevent damage. **[4]** In a machine installed in the automatic insertion area, where electronic microcomponents are installed in electronic boards, there is a pump that supplies water and a dryer for fast and efficient high pressure washing to remove impurities from the connections of electronic macro components **[5].** The oil pump is used to automatically supply oil to the conveyor belt motors by means of thin hoses, without the need to stop the production process. The high power bulbs are indicators of the operation of industrial equipment and machines, illustrating two colors, green indicating that it is operating and red representing inactivity due to failure or logistics when a product model change occurs, lack of raw materials or inadequate planning that sometimes happens in this company.

Manufacturing in the Electronics Industry

In every industry, there are different ways of developing manufacturing activities, the most common being those of linear process flows, in the form of U and T, or continuously with conveyor belts or in spaces attached to the continuous flow with work tables called manufacturing cells **[6,7].** Table 2 represents information on the types of processes with their productivity characteristics**. (Table 2)**

In the previous table, the main aspects of the types of processes most used in the electronic industry of Mexicali are observed, where the way of using them is evaluated textually, depending on the type of products, where various articles can be manufactured to market , being the linear and continuous where various articles are manufactured, in the U-structure they are diverse and exclusive and in the T-shaped and manufacturing cell they are exclusive because they require sophisticated manual operations. Regarding the operation, it is observed that the linear and continuous processes are automated in 70% with some activities elaborated by the human factor, the U-shape can be automated and manual, and instead the T type and manufacturing cell, are activities specialized manuals. The batch size in the linear and continuous processes is large, in the U-structure depending on the distribution it can be large or small, and the type T and manufacturing cell is small due to the specialized manufacturing characteristics of the manufactured articles **[8].** Finally, the speed factor is illustrated, where the linear and continuous processes require automated equipment and machines that carry out the activities at high speed, while the U type can have high and low speeds and the T-type and manufacturing cell , operate at low speed. It should be noted that the U-shaped process can be continuous with the characteristics of the linear, which is why it is represented in Table 2 with two options, depending on the production and distribution requirements of the plant. When used continuously, you have a large production line represented as a U, where the process begins at one point and its final stage is close to the start zone, manufacturing quickly with simple activities and equipment and automated machinery, and being U-shaped with workstations attached to a linear process, manufacturing is slow and manual activities **[9].**

Mathematical Simulation

One of the advantages of developing this activity is that it is possible to know aspects of importance in an industrial process, where based on equations and mathematical calculations, to determine the amount of industrial equipment and machinery and the specialized or non-specialized human factor to achieve optimum productive efficiency **[10].** This greatly helps to avoid unnecessary operations or the purchase of industrial equipment or machinery in a larger quantity than required and to have them unused, indicating a low level of productivity. Based on the aforementioned, with mathematical simulation, production predictions can be developed with the least amount of industrial equipment and machines, as well as the necessary personnel. Next, Table 3 shows the mathematical operations used by the PID, in its three types of operation: proportional, integral and derivative with their characteristics and the electronic components used**. (Table 3)**

Table 3 indicates the ways of operating a PID, which can be the three mathematical functions together or separately, depending on the way to carry out the control activity in industrial processes. Its application is very useful because according to each mathematical operation, it is determined whether it works in a constant error with the proportional reference stage for the feedback activity or with variable errors either with a +90 degree offset or -90 degrees at the sign of error. Figure 1 illustrates the three types of mathematical function, starting with the proportional type on the left, followed by the integral and finally the derivative. **(Figure 1)** shows the three types of PID control in the way represented in the simulation diagrams with MatLab specialized Simulink program **[11],** with the mathematical functions, indicating the way to operate continuously or out of phase at +90 degrees or -90 degrees. Degrees. Figure 2 illustrates the operation of the PID with the feedback activity where the control of the industrial process signal is elaborated and the action of adjusting the error with the three functions of the PID. The elaboration of these diagrams illustrates the control stages together with the feedback action with the industrial process activity that supports to reduce the error in each elaborated operation. **(Figure 2)**

Methodology

The research was carried out in two stages, the first being the simulation process with MatLab Simulink program, and the second the design,

Table 2. Types of manufacturing processes in the evaluated electronics industry.

Features	Type of products	Operation	Lot size	Velocity
Type				
Lineal	Diverse	Automatized	Big	High
Forma de U	Diverse, Exclusive	Automatized, Manual	Big, small	High, low
Forma de T	Exclusive	Manual	Small	Low
Continuo	Diverse	Automatized	Big	Low
Manufacturing cells	Exclusive	Manual	Small	Low
Source Investigation analysis of literature and experts				

Table 3. PID operations and operating factors.

Factors	Mathematical function	Electronic component	Operation
Type			
Proportional	Normal, f(t)	Resistor	Constant error
Integral	Integral, ∫f(t)dt	Capacitor	Variable error with offset of +90 grades
Derivative	Derivate d' (f(t))	Inductor	Variable error with offset of -90 grades
Source Investigation analysis of literature and experts			

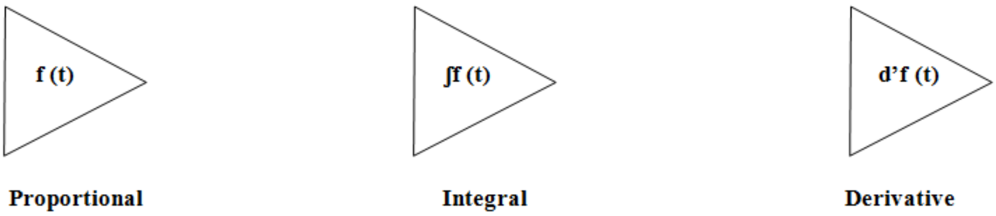

Figure 1. Types of PID control.

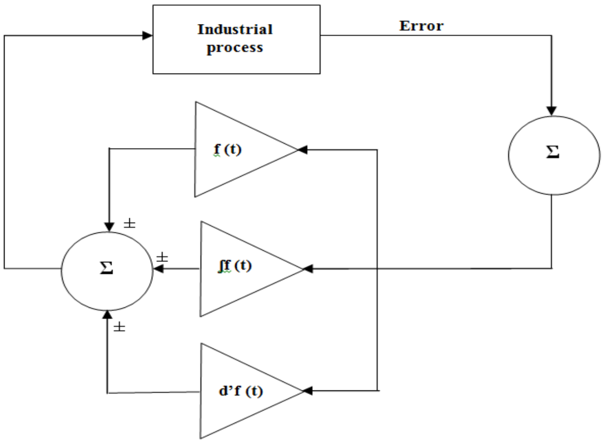

Figure 2. Representation of PID operation with the three functions.

manufacture and application of the PID system as a whole. Next, what is developed in the two stages is explained in detail:

Stage 1. The mathematical analysis with the Simulink generated the development of figures expressed in an interconnected diagram to elaborate the mathematical operations and be represented by sections or as a final result in a graph or monitoring with real values and drawing comparative data from Standardized reference according to what is required by the industrial equipment and machines, indicating the way in which each section of the PID works and with it the way to elaborate the control depending on the industrial operation to control.

Stage 2. A PID device with electronic components was developed, represented by resistors, capacitors and low-power coils, with a specialized electrical relay being a component that operated as it is made together with a capacitor and a coil, to elaborate the conversion process Low power 12 volt direct current to 120 volt AC power.

The applied PID was designed by the investigators participating in the research.

Results

The use of PID in a stage of the process that reflected a drop in its productivity levels, greatly helped to reduce the errors that occurred in the three types of process flow (linear, continuous and U-shaped, for sophisticated activities) used in this evaluated electronic industry.

Productivity and Quality Evaluation

The application of the PID in some strategic stages that contain industrial equipment and machinery in the evaluated company, generated increases in the quantity of manufactured products and in the percentage levels of quality, observing this information in Tables 4 and 5, being with a comparative analysis on line 1 in table 4 with the use and without using the PID, contemplating fast washing and drying operation with the water pump and dryer and the motor on the conveyor belt that were controlled with the PID. In this evaluation, the manufacture of cell phones was analyzed. Table 5 represents the same analysis for line 2. **(Table 4, 5)**

Table 4. Comparative analysis of productivity online 1 (2018).

Month	Without PID	With PID	Without PID	With PID
January	8978	11756	67	82
February	9324	11980	70	81
March	9789	12314	65	84
April	10054	12765	71	87
May	10113	13111	76	88
June	10222	13246	73	89
July	10279	13359	75	84
August	10377	13569	76	82
September	10401	13824	73	88
October	10362	13449	70	85
November	10008	13126	75	84
December	9789	12543	72	84

Table 5. Comparative analysis of productivity online 2 (2018).

Month	Without PID	With PID	Without PID	With PID
January	7678	9889	62	79
February	7980	10023	68	80
March	8049	10472	61	87
April	8601	10991	69	84
May	8993	11469	70	80
June	9567	11985	72	82
July	9854	12589	71	86
August	10468	12921	77	84
September	10177	12734	75	83
October	9756	12233	73	82
November	9345	11957	74	85
December	8890	11578	76	88

Tables 4 and 5 indicate the production and quality indexes, observing that in January an operating capacity of 70% of the industrial machinery and equipment and the human factor began, and as the months of the year evaluated went by, that capacity increased to 85, without being the maximum of 100% to avoid overheating, mainly because the industry located in Mexicali, with temperature levels inside industrial plants of up to 45°C in the summer without air conditioning and 32°C using air conditioning, and the heat from the environment is added to that of the machines, reaching 37°C with air conditioning. It is also illustrated that it started with a number of products manufactured in the month of January and it went up until reaching its maximum capacity in the month of August and from there it began to drop until the month of December 2017 when the evaluation. Table 4 also represents a considerable difference of around 23% in the quantity of products and around 19% on average in the quality indices, when comparing not using the PID and being used as a control activity of industrial equipment and machines. Table 5 shows the same evaluation process as Table 4, illustrating only a smaller number of manufactured products with differences in production and quality of around 2 7% and 17% as average levels. The comparative analysis from January to December 2018, is prepared by using half of each eight-hour shift without using the PID and half of the time using for management and supervisory personnel to consider the need to use the PID, being two shifts from 6AM to 2PM (shift 1) and from 2PM to 10PM (shift 2), thus obtaining the comparative analysis.

Simulation Analysis

The mathematical simulation evaluation of the application of the PID, indicates for each line (1 and 2) analyzed, the diagrams expressed in Figures 3 and 4, where the mathematical equations are observed as Laplace transform functions for each section of the PID, being the simplest is the proportional one and the other two are functions obtained in the inverse sense representing the offset functions of +90 degrees and -90 degrees. Once the mathematical model with the diagram of the functions of the PID, the industrial process analyzed, and a graph with various simulations of evaluations had been developed, the design, manufacture, and testing of each section of the PID were prepared to couple them for the activities of control in lines 1 and 2 analyzed, in order to obtain real data and carry out a comparative study applying the PID and without using it, as shown in Tables 4 and 5.

Figure 3 shows the diagram of line 1 with the proportional with a simpler function than the other two, with complex equations, the one with the integral being the numerator with a quadratic level and the denominator with a simple scale being the derivative with the single-level numerator. and the denominator of the quadratic scale. The same happened with figure 4, regarding the mathematical functions, representing the actions of line 2, where there was a smaller amount of industrial equipment and machinery and human resources that supported manual activities coupled with automated operations controlled by the PID. At each strategic stage of the process evaluated.

PID Operational Evaluation

In order to determine the operating efficiency of the installed PID in the required steps of the manufacturing areas, values were obtained constantly in the different sections of PID and compared with standard reference data. The analysis is shown in tables 6 for line 1 and 7 for line 2, indicating the values in the PID sections. **(Table 6)** shows information on the operation of the three sections of the PID evaluating levels of current and direct and alternating voltage, in the activation components (in the 2N2222 transistor) and in the 12 volts relay with DC and to 120 volts of AC. The analysis was made from April to December 2017, which was at the time the PID application was developed, and being the time to convince to managers and supervision personnel, with the having evaluations from January to March of 2017, and observe low production rates. Table 7 represents an analysis similar to that of Table 6, with one aspect of interest observed and was made pilot test in April indicating in each table that the month was not in full control of the PID due to the coupling of its sections and with the equipment and industrial machinery of each manufacturing line evaluated**. (Table 7)**

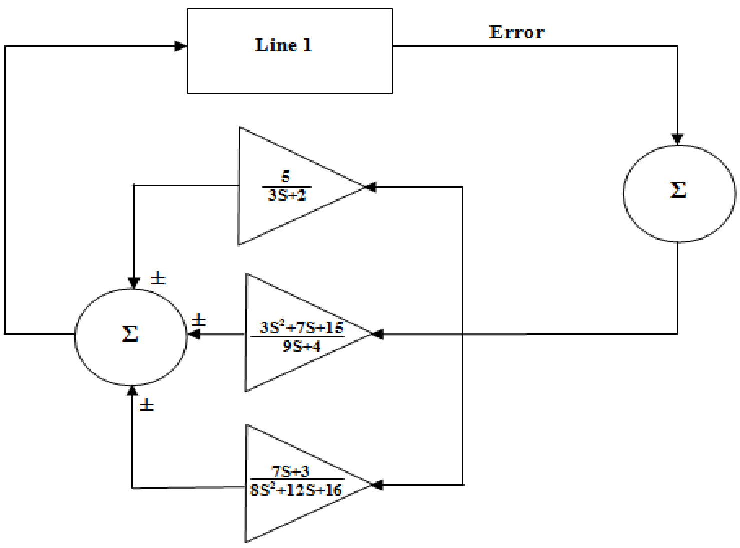

Figure 3. Analysis with PID in stage 1 of the manufacturing process.

Table 6. Analysis of the operation of the PID in line 1 (April to December 2017).

Type Month	Proportional	Integral	Derivative
April	Current and voltage out of proper range	Current and voltage out of proper range	Current and voltage out of proper range
May	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
June	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
July	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
August	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
September	Current and voltage out of proper range	Current and voltage out of proper range	Current and voltage out of proper range
October	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
November	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
December	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range

Table 7. Analysis of the operation of the PID in line 2 (April to December 2017).

Type Month	Proportional	Integral	Derivative
April	Current and voltage out of proper range	Current and voltage out of proper range	Current and voltage out of proper range
May	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
June	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
July	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
August	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
September	Current and voltage out of proper range	Current and voltage out of proper range	Current and voltage out of proper range
October	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
November	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range
December	Current and voltage in proper range	Current and voltage in proper range	Current and voltage in proper range

Conclusion

The use of PID in the electronics industry evaluated was of great importance because increased the production and quality levels, and with this increased the productivity to use industrial equipment and machinery in a very efficient way, saving consumption of electrical energy and to the personnel in an optimal way, generating cost savings and preparing the delivery between the manufacturing areas of the evaluated industry and the client, achieving adequate satisfaction for the products manufactured. Managers and supervision personnel avoided worrying about the situation of low productivity levels presented before the PID were applied in the strategic steps of the manufacturing areas and supports in the innovation of the development of the new PID that are in the process of patent analysis in Mexico. The elaborate coupling between the three PID sections at each step and the researchers supports to have an optimal function of industrial equipment and machinery, learning about the industrial process very fast in the electronics industry analyzed, and generating rapid coupling of the PID to the manufacturing areas evaluated.

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