PID AND FUZZY-PID CONTROLLER FOR VARIOUS ELECTRICAL MACHINE APPLICATIONS: A COMPARATIVE STUDY

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Abstract— **This report gives the review on the history of PID controllers, their tuning aspect then eventually the incorporation of fuzzy with PID and see how it has enhanced accuracy and flexibility of controllers. A PID controller comprises three kinds of controller, namely proportional (P), integral (I), and derivative (D). In control system, designing a PID controller is mostly used when the mathematical representation of a plant (system to be controlled) is unknown. Therefore, PID controllers are mostly set and tuned on the field [1] for practical reason. Since the concept of the fuzzy control was first introduced, many applications in control systems have received much attention and interest in recent years.**

Keywords— **PID Controller, Fuzzy, Defuzzification.**

I. INTRODUCTION

PID (proportional integral derivative) control is one of the earlier control strategies. Its early implementation was in pneumatic devices, followed by vacuum and solid state analog electronics, before arriving at today's digital implementation of microprocessors. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. Since many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control. According to a survey for process control systems conducted in 1989, more than 90 of the control loops were of the PID type. PID control has been an active research topic for many years sees the monographs. Since many process plants controlled by PID controllers have similar dynamics it has been found possible to set satisfactory controller parameters from less plant information than a complete mathematical model. These techniques came about because of the desire to adjust controller parameters in situ with a minimum of effort, and also because of the possible difficulty and poor cost benefit of obtaining mathematical models. [2]

The PID controller tuning methods are classified into two main categories

- Closed loop methods
- Open loop methods

Closed loop tuning techniques refer to methods that tune the controller during automatic state in which the plant is operating in closed loop. The open loop techniques refer to methods that tune the controller when it is in manual state and the plant operates in open loop. The closed loop methods considered for simulation are:

- -Ziegler-Nichols method
- -Modified Ziegler-Nichols method
- -Tyreus-Luyben method
- -Damped oscillation method
- Open loop methods are:
- -Open loop Ziegler-Nichols method
- -C-H-R method
- -Cohen and Coon method
- -Fertik method
- -Ciancone-Marline method
- -IMC method
- -Minimum error criteria (IAE, ISE, ITAE) Method

As the order of the plant increase the conventional tuning methods of PID controller do not show satisfactory results, thus simple methods like fuzzy PID controller are opted.

A PID-like (proportional plus integral plus derivative, PID) fuzzy logic controller (FLC), or simply PID-like FLC, algorithms have been and continue to be a very active and fruitful research field since Mamdani and Assilian pioneering work on fuzzy controller in 1974 ; the controller is shown in . The impetus behind this conventional PID algorithms has been successfully used in the process industries since 1940s and remains the most commonly used algorithm today, while numerous application of fuzzy logic control (FLC) have immerged covering a wide range of practical areas and that many software and hardware products for fuzzy control have been commercialized during the last few years. Because designing methods of PID-like FLC emulates human control strategy, their principles are easy to understand for non-control specialists. During the last two decades, designing methods of conventional PID-like controller have been using more and more advanced mathematical tools. This is needed in order to solve difficult problems in a rigorous fashion. However, this also results in fewer and fewer practical engineers who can understand these design methods. Therefore, practical engineers who are on the front line of designing consumer products tend to use the approaches that are simple and easy to understand. Design method of the PID-like FLC is just such approaches.

II. SUMMARY

The conventional fuzzy two-term control has two different types: one is Fuzzy- Proportional-Derivative (fuzzy-PD) control which generates a control output from the error and the change rate of error and is a position type control; the other is the Fuzzy-Proportional-Integral (fuzzy-PI) control which generates incremental control output from the error and the change rate of error and is a velocity type control. These two controllers follow some rules. To allow the fuzzy-PD controller to be like a position type control and the fuzzy-PI controller to be like a velocity type control. However we do not know the relationship between fuzzy-PID controller and the traditional PID controller. In this paper we try to give a mathematics proof to ensure that a fuzzy-PID controller (using the minimum inference engine and center average defuzzification) is a parameter varying PID controller. The PID type fuzzy controller was given . There is a mathematics proof to ensure that PID type fuzzy controller behaves like a parameter time-varying PID controller. We will use the similar mathematics method to show that a special kind of fuzzy-PID controller, a fuzzy controller using the minimum inference engine and center average defuzzification, behaves like a parameter time-varying PID controller. If we can give mathematics proof to ensure the fuzzy controller behaves like a parameter time varying PID controller; we can predict some performance when designing a controller.

FLC-PI controllers are quite simple, though they are most widely used in practice in practice and provides similar results to conventional controllers. But in some applications it may be useful to employ more general controllers, which make it easier to reach the system specifications and improve their performance, though they be more difficult to tune.

III. LITERATURE SURVEY ON PID CONTROLLERS AND THEIR TUNING

The two most popular PID techniques were the step reaction curve experiment, and a closed-loop “cycling” experiment under proportional control around the nominal operating point. In this several useful PID-type controller design techniques is presented, and implementation issues for the algorithms isl also discussed. The proportional, integral, and derivative actions are explained in detail, and some variations of the typical PID structure are also introduced. The well-known empirical Ziegler– Nichols tuning formula and modified versions is covered. Approaches for identifying the equivalent first-order plus dead time model, which is essential in some of the PID controller design algorithms, is presented. A modified Ziegler–Nichols algorithm is also given. Some other simple PID setting formulae such as the Chien–Hrones–Reswick formula, Cohen–Coon formula, refined Ziegler–Nichols tuning, Wang–Juang–Chan formula and Zhuang–Atherton optimum PID controller is presented. The PID tuning formulae for FOIPDT (first- order lag and integrator plus dead time) and IPDT (integrator plus dead time) plant models, rather than the FOPDT (first-order plus dead time) model, is given. A graphical user interface (GUI) implementing hundreds of PID controllers tuning formulae for FOPDT model is given [2].

Probably the best simple PID tuning rules in the world written By Sigurd Skogestad in 2001. The aim of his work is to present analytic tuning rules which are as simple as possible and still result in a good closed-loop behavior. The starting point has been the IMC PID tuning rules of Rivera, Morari and Skogestad (1986) which have achieved widespread industrial acceptance. The integral term has been modified to improve disturbance rejection for integrating processes. This is much simpler and appears to give controller tunings with comparable performance. All the tunings have been derived analytically and are thus very suitable for teaching. Conclusion two-step procedure is proposed for deriving PID tunings for typical chemical processes.

1. The half rule is used to approximate the process as a first or second order process with effective delay.
2. Based on this process model with parameters k, $\tau 1$ and θ the following SIMC tunings are suggested [3].

Comparison of some well-known PID tuning formulas by Wen Tan a, Jizhen Liu a, Tongwen Chenb, Horacio J. Marquez b a Zhu xinz huang, Dewai, in 2006. Criteria based on disturbance rejection and system robustness were proposed to assess the performance of PID controllers. A simple robustness measure is defined and the integral gains of the PID controllers are shown to be a good measure for disturbance rejection. An analysis of some well-known PID tuning formulas reveals that the robustness measure should lie between 3 and 5 to have a good compromise between performance and robustness [4].

In 2007, Relay Auto Tuning Of Parallel Cascade Controller by Sathe Vivek and M. Chidambaram presented work concerned with relay auto tuning of parallel cascade controllers. The method proposed by Srinivasan and Chidambaram to analyze the conventional on-off relay oscillations for a single loop feedback controller is extended to the relay tuning of parallel cascade controllers. Using the ultimate gain and ultimate cross over frequency of the two loops, the inner loop (PI) and outer loop (PID) controllers are designed by Ziegler-Nichols tuning method. The proposed methods give an improved performance over that of the conventional on-off relay tune method. The modified analysis of relay auto tuning proposed for single feedback system by Srinivasan and Chidambaram and modified analysis of asymmetric auto tuning by them are extended to tune parallel cascade controllers. Both the methods effectively take care of higher order harmonics [5].

Observations on PID control for unknown systems by Pasi Airikka, Pasi Airikka in 2008 says that this paper presents some fundamental, elegant and general observations on SISO (Single-Input-Single-Output) PID control without knowledge on the process model, or in some cases, with using only the minimum knowledge of the process model. Some elegant and interesting observations on SISO (Single-Input Single-Output) PID control were announced in this paper. The observations were wrapped around responses due to either set point or load disturbance excitation. The integrated error is rather applicable for both control design and control performance assessment but also for identifying process model parameters such static gain and dead time which can be solved explicitly for given assumptions. Most observations given in this paper did not require knowledge on the PID controlled process at all while some other observations did require minimal knowledge of the system such as static process gain. Surprisingly, a lot of general observations can be stated on PID control without any knowledge of the system dynamics [6].

Finn Haugen in July 2010 presented article that describes the closed-loop method, while the open-loop method is described in another article (available at http://techteach.no). Ziegler and Nichols used the following definition of acceptable stability as a basis for their controller tuning rules: The ratio of the amplitudes of subsequent peaks in the same direction (due to a step change of the disturbance or a step change of the set point in the control loop) is approximately 1/4. The responses in the control system may become unsatisfactory with the Ziegler-Nichols' method. 1/4 decay ratio may be too much, that is, the damping in the loop is too small. A simple re-tuning in this case is to reduce the Kp somewhat, for example by 20%. [7]. He in 17. July 2010 presented another article that describes the open-loop method. Calculated the controller parameters according to . After the controller parameters have been calculated and entered into the PID controller, the control loop is closed (by setting the controller in automatic mode) [8].

A Simple Approach to Design of Variable Parameter Nonlinear PID Controller was done by Omer Aydogdu and Mehmet Korkmaz + Selcuk in 2010. In his paper, a dynamic PID controller that changes parameters over time according to the error response is proposed. Synthesis and analysis of the proposed PID controller is realized easily and the system shows good performance measurement from the simulations. Consequently, his method presents lower overlapping, short settling time than Ziegler – Nichols, for the third order systems. The simulation results show that nonlinear PID form, which is mentioned, are better. And this method is simple and effective beside this, these basic formulas can be used even microcontrollers which have the lower processors. In practice, this method can be implemented systems which are not higher speed and have no much memory since the calculations of Kp, Kd, Ki are basic [9]

In 2012 Kappa-tau type PI tuning rules for specified robust levels byJuan J. Gude and Evaristo Kahoraho. New tuning rules for 2-DoF PI controllers in the spirit of the kappa-tau ones are addressed in his paper. In particular, tuning rules have been devised in order to minimize the integrated absolute error with a constraint on the maximum sensitivity. The tuning rules are shown to give good results compared to a couple of well established classical and modern tuning methods, especially when simplicity, performance and robustness are emphasized. Future investigation should rely on extending these tuning rules to integral processes and applied to PID and fractional PID controllers [10].

Pseudo-PID Controller: Design, Tuning and Applications by Antonio S. Silveira, Antonio A. R. Coelho, Aline A. Franca, Valter L. Knihs . In this paper, a pseudo PID (PPID) controller, including only one gain to be tuned, is proposed. The idea is to connect the I+PD control design with the Fertik and Ziegler-Nichols tuning rules in order to obtain not only a simple and efficient control algorithm but also to decrease the operator intervention time with respect to the calibration task and to obtain desired closed-loop dynamic. Three approaches for stable automatic tuning via, self-tuning, internal model control and small gain theorem, are investigated for adjusting the tuning parameter of the controller. In their paper they have proposed a pseudo PID controller design that can be interesting from several viewpoints: as a general purpose device, it provides a good dynamic loop performance, presents one calibration parameter, is simple to implement, easy to use and maintain, is applicable in a variety of plant classes [11].

Comparison of PID Controller Tuning Methods by Mohammad Shahrokhi and Alireza Zomorrodi. His study is comparison of tuning methods for single input single output systems using computer simulation. Integral of the absolute value of the error has been used as the criterion for comparison. These tuning methods have been implemented for first, second and third order systems with dead time and for two cases of set point tracking and load rejection. ISE method for first order and second order systems when we have disturbances gives the minimum IAE value [12].

IV. LITERATURE SURVEY ON FUZZY AND FUZZY PID CONTROLLERS

easy Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999 History of Fuzzy Logic •1964: Lotfi A. Zadeh, UC Berkeley, introduced the paper on fuzzy sets. Idea of grade of membership was born 1965-1975: Zadeh continued to broaden the foundation of fuzzy set theory

•1970s: research groups were form in JAPAN 1974: Mamdani, United Kingdom, developed the first fuzzy logic controller

•1977: Dubois applied fuzzy sets in a comprehensive study of traffic conditions •1976-1987: Industrial application of fuzzy logic in Japan and Europe •1987-Present: Fuzzy Boom [13].

In 2009 comparison of mamdani and sugeno fuzzy inference system models for resonant frequency of rectangular microstrip antennas by K. Guney and N. Sarikaya . Models based on fuzzy inference systems (FISs) for calculating the resonant frequency of rectangular microstrip antennas with thin and thick substrates are presented. Two types of FIS models, Mamdani FIS model and Sugeno FIS model, are used to compute the resonant frequency. The parameters of FIS models are determined by using various optimization algorithms. The resonant frequency results predicted by FIS models are in very good agreement with the experimental results available in the literature [14].

Fuzzy Logic Based Set-Point Weight Tuning of PID Controllers by Antonio Visioli in 1999 proposed, a novel methodology, based on fuzzy logic, for the tuning of proportional-integral-derivative (PID) controllers. A fuzzy inference system is adopted to determine the value of the weight that multiplies the set-point for the proportional action, based on the current output error and its time derivative. The tuning of the parameters of the fuzzy module can be easily done by hand or by means of an autotuning procedure [15].

A Fuzzy PID Controller Being Like Parameter Varying PID by Tsung-Tai Huang,*Hung-Yuan Chung and Jin-Jye Lin in 1999 .A fuzzy-PID controller using the minimum inference engine and center average defuzzification is analyzed and shown that it behaves approximately like a parameter varying PID controller. They then tried to analyze the effect of this kind of controller when using different rule bases. Simulation results are used to demonstrate the feasibility of this method. The dynamic behavior of the fuzzy-PID controller using minimum inference engine and center average defuzzification behaves approximately like a parameter varying PID controller. They have shown that the fuzzy-PD controller will cause a steady-state error for a type 0 system no matter what kind of rule base is utilized. The fuzzy-PI controller will still have the performance like a parameter varying PI controller, no matter what kind of fuzzy rule base is utilized. We can also see that the controller via fuzzy-PD rule base has smaller rising time than that via fuzzy-PI rule base [16].

Analysis of Direct Action Fuzzy PID Controller Structures by George K. I. Mann, Bao-Gang Hu, in june 1999.Proposed simple analytical procedure is developed to deduce the closed form solution for a three-input fuzzy inference. This solution is used to identify the fuzzy PID action of each structure type in the dissociated form. The tuning characteristics of different fuzzy PID structures are evaluated with respect to their functional behaviors. The rule decoupled and one-input rule structures proposed in this paper provide greater flexibility and better functional properties than the conventional fuzzy PID structures [17].

In 1999 Fuzzy Logic Based Set-Point Weight Tuning of PID Controllers by Antonio Visioli proposed a a novel methodology, based on fuzzy logic, for the tuning of proportional-integral-derivative (PID) controllers. A fuzzy inference system is adopted to determine the value of the weight that multiplies the set-point for the proportional action, based on the current output error and its time derivative. In this way, both the overshoot and the rise time in set-point following can be reduced. The values of the proportional gain and the integral and derivative time constant are determined according to the well-known Ziegler–Nichols formula so that good load disturbance attenuation is also assured. The methodology is shown to be effective for a large range of processes and is valuable to be adopted in industrial settings since it is intuitive, it requires only a small extra computational effort, and it is robust with regard to parameter variations. The devised control structure seems to be particularly appropriate to be adopted in industrial settings, since it requires a small computational effort, it is easily tuned and it is compatible with a classical PID controller; that is, it consists of a module that can be added or excluded without modifying the parameters of the existing PID [18].

In 2000, Maribor and Marjan Golob Slovenia presented on PID and Fuzzy Control of a Magnetic Suspension System .In this paper, two types of decomposed proportional integral-derivative (PID) based fuzzy logic controllers are applied to a simple magnetic suspension system. Results are compared with results obtained from optimal linear PID control design. An important feature of decomposed fuzzy PID controller is their simple structure. In its simplest version, it uses a three one-input one-output fuzzy inferences with three separate rule-bases with simple rules. All controllers has been realized by the same hardware and software tools. By testing it was formed out that the both fuzzy PID controllers gives better performance over a typical operational range then a traditional linear PID controller. An approach of controlling the magnetic suspension system based on the fuzzy logic has been presented [19].

In 2005, Self-Tuning Fuzzy PID Controller on PLC the self-tuning method for fuzzy PID controllers that has been developed in a previous study of the authors is implemented on PLC in order to control some standard processes formed. In this tuning method, the input scaling factor corresponding to the derivative coefficient and the output scaling factor corresponding to the integral coefficient of the fuzzy PID controller are adjusted using a fuzzy inference mechanism with a new input called \normalized acceleration". The results of the implementation have been compared with those of the classical fuzzy PID controller without a tuning mechanism and it has been observed that the tuning mechanism decreases the oscillations and the settling time while providing smoother system responses also in real time application [20].

An intelligent hybrid fuzzy PID controller by Isin Erenoglu Ibrahim Eksin Engin Yesil Mujde Guzelkaya in 2006, introduced a design methodology that blends the classical PID and the fuzzy controllers in an intelligent way. Basically, in this design methodology, the classical PID and fuzzy controller have been combined by a blending mechanism that depends on a certain function of actuating error. Moreover, an intelligent switching scheme is induced on the blending mechanism that makes a decision upon the priority of the two controller parts; namely, the classical PID and the fuzzy constituents. Here, only two of these simulations are given and the proposed hybrid fuzzy PID controller is compared to the pure classical PID or the pure fuzzy controller applications. All of the simulation results have shown that the proposed hybrid structure has provided a good and effective performance on system response [21].

Fuzzy based PID Controller using VHDL for Transportation Application by Md. Shabiul Islam, Nowshad Amin, Mukter Zaman, M.S.Bhuyan. In their work designing of PID-type (Proportional-Integral-Derivative) controller based on Fuzzy algorithm using VHDL to use in transportation cruising system. The cruising system with

Fuzzy concept has developed to avoid the collisions between vehicles on the road. The developed Fuzzy Logic Controller (FLC) provides a reference for controlling the vehicle speed either increase or decrease [22].

Design of Gain Scheduled Fuzzy PID Controller by Leehter Yao and Chin-Chin Lin in 2007 proposed an adaptive fuzzy PID controller with gain scheduling. The structure of the proposed gain scheduled fuzzy PID (GS_FPID) controller consists of both fuzzy PI-like controller and fuzzy PD-like controller. Both of fuzzy PI-like and PD-like controllers are weighted through adaptive gain scheduling, which are also determined by fuzzy logic inference. A modified genetic algorithm called accumulated genetic algorithm is designed to learn the parameters of fuzzy inference system. The proposed gain scheduled fuzzy PID controller performs well when controlling the system without varying dynamics. Since the proposed gain scheduled fuzzy PID controller is with more parameterization degree of freedom, it can be utilized to control more complex systems which generally cannot be controlled well by the regular fuzzy PID controllers [23].

Real-Time Performance Evaluation of a Fuzzy PI + Fuzzy PD Controller for Liquid-Level Process by Vineet, K.P.S. Rana and Vandna GUPTA in 2008 did a comparative study to evaluate the real-time performance of fuzzy proportional-integral plus fuzzy proportional-derivative (Fuzzy PI + Fuzzy PD) controller with the real-time performance of Conventional PI for a liquid-level process experiment. The performance of controller in cascade configuration was better than feedback configuration with respect to the performance criteria. It was observed that the Fuzzy PI + Fuzzy PD controller in cascade configuration (in primary controller) perform superior than the conventional PI controller in both the feedback and cascade control configuration and fuzzy controller in feedback loop configuration [24].

Design and Implementation of Digital Fuzzy-PID Controller Based on FPGA by Wen Chen and Hui- proposed that in order to solve the problem of precise control of non-linearity system, a Digital Fuzzy-PID controller is designed by combining the advantages of fuzzy inference and PID controller based on FPGA. It has a strong capability of adapting to the significant changes of system parameters because of the combination of fuzzy logic control (FLC) and linear control theory (PID control). Since the resultant control law has an analytical form and the number of fuzzy control rules is rather small, controller designers can expect an effective implementation of a control system. So The Digital Fuzzy-PID controller can be deployed in a variety of nonlinear control systems with time-varying characteristics, pure delay, and large time constants [25].

Comparison between Conventional and Fuzzy Logic PID Controllers for Controlling DC Motors by Essam Natsheh1 and Khalid A. Buragga in 2010 compared Fuzzy logic and proportional-integral-derivative (PID) controllers are for use in direct current (DC) motors positioning system. A simulation study of the PID position controller for the armature-controlled with fixed field and field controlled with fixed armature current DC motors is performed. Fuzzy rules and the inferencing mechanism of the fuzzy logic controller (FLC) are evaluated by using conventional rule-look up tables that encode the control knowledge in a rules form. The design and implementation of armature-controlled and field-controlled DC motor system using both conventional PID and PID-like FLC have been done. Comparisons of experimental results of the conventional PID controller and PID-like FLC show that the PID-like FLC is able to perform better than the conventional PID controller. Results indicate that even without knowing the detail of the control plants, we were able to construct a well performed fuzzy logic controller based on the experience about the position controller [26].

A Comparative Study of P-I, I-P, Fuzzy and Neuro-Fuzzy Controllers for Speed Control of DC Motor Drive by S.R. Khuntia, K.B. Mohanty, S. Panda and C. Ardil presented a comparative study of various controllers for the speed control of DC motor. The most commonly used controller for the speed control of dc motor is Proportional- Integral (P-I) controller. However, the P-I controller has some disadvantages such as: the high starting overshoot, sensitivity to controller gains and sluggish response due to sudden disturbance. So, the relatively new Integral-Proportional (I-P) controller is proposed to overcome the disadvantages of the P-I controller. Further, two Fuzzy logic based controllers namely; [27].

Hybrid system based Fuzzy-PID control schemes for unpredictable process by M.K. Tan, C.S.X. Loh and K.T.K. Teo in july 2011 proposed an optimization scheme using hybrid of Q-learning (QL) and genetic algorithm (GA) to optimize the fuzzy membership function in order to allow the conventional fuzzy-PID controller to control the process temperature more effectively. The performances of the proposed optimization scheme are compared with the existing fuzzy-PID scheme. The results show that the proposed optimization scheme is able to control the process temperature more effectively even if disturbance is introduced [28].

PID Versus Fuzzy Logic Based Intelligent Controller Design for a Non Linear Satellite's Attitude Control: Performance Analysis using MATLAB/Simulink by E Venkata Narayana, Vidya Sagar Bonu, G Mallikarjuna Rao in 2011 evaluated the performance of conventional PID (Proportional, Integral and Derivative) controller with respect to the proposed fuzzy based intelligent controller in the process of controlling the attitude of a spacecraft-satellite system. In general this attitude is having non linearity in behavior. Hence, offers major constraint in using the conventional PID controller. Also PID controller offers a major constraint in the selection of controller gains. In this work fuzzy logic based intelligent controller design is introduced for controlling non linear spacecraft-satellite attitude control system [29].

Research on Adaptive Fuzzy PID Synchronous Control Strategy of Double-Motor Biao YU , Suzhou, and Chi XUE , Suzhou. In their paper, adaptive fuzzy PID which can tune the parameters on-line is introduced to apply in the double-motor synchronous control system. In MATLAB / SMULINK simulation environment, the speed of master motor is perfectly followed by slave motor, and high robustness and precision are obtained. The simulation results show that fuzzy logic PID control strategy has better performances than traditional controller. A control strategy combining PID with fuzzy theory is introduced in this paper. It can tune the parameters online by itself to adapt the dynamic change of the controlled system. It is applied in the double-motor synchronous working system, which is so widely used in the industry producing [30].

Fuzzy Adaptive PID for Flow Control System based on by R. Manoj Manjunath ,S. Janaki Raman designed fuzzy adaptive PID control algorithm based on OPC (Open Process Control) for the flow process station to improve the control performance better than the conventional PID controller. PID controller works well only if the mathematical model of the system could be computed. two input and three output self adapting fuzzy PID controller was designed to control the final control element of the flow process station [31].

Comparison of Conventional and Fuzzy P/PI/PD/PID Controller for Higher Order Non Linear Plant with High Dead Time by Preeti, Dr. Narendra Singh Beniwal designed Fuzzy controller for the system having higher order and high dead time. Performance table shows the affects of the proposed Fuzzy Logic Controllers as compared to the zeiglar niholas tuned Conventional Controllers [32].

Study of Fuzzy-PID Control in MATLAB for Two-phase Hybrid Stepping Motor by ZHANG Shengyi and WANG Xinming have done the simulation for a conventional PID controller and the Fuzzy-PID controller, and the result shows that the setting time and the maximum overshoot value is greatly reduced for the fuzzy-PID controller, and the performance of fuzzy-PID controller is better than conventional PID algorithm. Based on the selected model for two-phase hybrid stepping motor, the simulation in MATLAB/simulink is done, and the data is analyzed, for the conventional PID controller [33].

V. CONCLUSIONS

1. Advantage of using FPID is that it is successful in overcoming transient and steady state errors.
2. Disadvantage of FPID is that tuning aspect remain still a matter of question.
3. Ziegler-Nichols tuning rules are mostly useful when the plant's mathematical representation cannot be obtained. It gives the engineers a tuning process starting point with ease. However, these tuning rules are also applicable for those systems with known mathematical models. The Ziegler-Nichols method gives the starting point for the tuning process.
4. A pseudo PID controller design that can be interesting from several viewpoints: as a general purpose device, it provides a good dynamic loop performance, presents one calibration parameter, is simple to implement, easy to use and maintain, is applicable in a variety of plant classes.
5. The complete study of fuzzy controllers should involve all the terms that characterize the conventional ones. The addition of derivative term makes it possible to show the nonlinear characteristic of fuzzy controller, as well as to enlarge the variation range of the other input variables by means of their gains so as to improve the controller behavior. The quantitative study of these FLC-PID has helped to produce some rules for the finer adjustments by means of the effects of parameters on system response. However the subject of the design and the tuning of general fuzzy controllers is a problem that remains open.
6. FPID can tune the parameters online by itself to adapt the dynamic change of the controlled system. It is applied in the double-motor synchronous working system, which is so widely used in the industry producing. This adaptive fuzzy PID strategy can control the double-motor system more effectively with faster response speed, shorter setting time, stronger robustness and less overshoot, as well as better synchrony. These performances can hardly be achieved by traditional PID controller. And the Adaptive Fuzzy PID controller will have major significance in practical industrial processes as well as theory development.
7. A two-input FPID controller implemented on a PLC and it has been used to control first and Second-order systems with dead time formed on a process simulator. The input scaling factor corresponding to the derivative coefficient and the output scaling factor corresponding to the integral coefficient of the two input FPID controller can be adjusted using a relative rate observer based tuning method. The relative rate observer method provides a satisfactory response with only one parameter adjustment.

VI. RECOMMENDATIONS

1. 1 Future work will include the PPID implementation in multivariable applications in order to verify its suitability in coupled and decoupled systems as a good field device in process control scenarios.

2. FPID can tune the parameters online by itself to adapt the dynamic change of the controlled system. It is applied in the double-motor synchronous working system, which is so widely used in the industry producing.

3. FPID can satisfactorily be applied in any kind of electrical machines with little advantage and certain disadvantages than PID.

4. Simulation of FPID on drives can be implemented to produce desired results.

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