ProportionalControllers for application in power electronic systems

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ABSTRACT

In this paper, a new simple derivation of all stabilizing proportional controllers, for first order linear time invariant systems with time-delay, is presented. Although several results based on the Hermite-Biehler theorem for finding such a set of controllers exist, the aim of this article is to present a shorter and more instructive derivation, which can be followed easily.

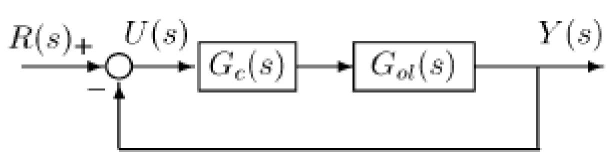
Key Words: *Stabilization, time-delay systems, PID control, robust control.*

INTRODUCTION -

For control systems, the stability problem, which is the first and foremost important requirement of the design, has been investigated by researchers for many years. When designing a controller for a system, possession of the set of all stabilizing controller parameters is important. Since this concept possesses advantages over tuning the controller, in other words, finding a "good" set of stabilizing parameters that optimizes a particular performance criterion. For high order plants, that are closer to real systems, obtaining the signs of the elements in the first column of Routh's array is difficult because these elements have the following form: , where is the order of the plant, is the P controller gain, and have polynomial dependence on . Based on this difficulty, almost all control engineering books restrict this kind of analysis only to low order plants.However, the time-delay case is not as straightforward as the delay-free case. For time-delay systems, the closed-loop system characteristic equation becomes a quasipolynomial and assessing the stability of a quasipolynomial is much more complicated than that of a polynomial, since the former has an infinite number of roots. As a result of that, simple controller (such as P, PI, and PID) design for such systems become quite difficult. Nonetheless, there exist some methods for determining all stabilizing low-order controllers for time-delay systems.

In this paper, the stability analysis presented in utilized in order to calculate all stabilizing values of proportional controllers for first order systems as achieved i the Hermite-Biehler Theorem for quasipolynomials.

Direct Method for MATLAB Implementation –



MATLAB is a powerful and versatile simulation software, which is user-friendly, very easy to learn, and a standard in software tools for solving scientific and technical calculation. MATLAB also has toolboxes in various fields, such as control systems, fuzzy logic, neural network, nonlinear control design, optimization, robust control, and signal processing. MATLAB package and the MATLAB Control System Toolbox are used to aid in the design of controllers in control system classes.

This paper presents a solution for the problem stated above: a direct method and its implementation in MATLAB language, to determine the stability range for feedback systems with P controllers. This program works for high order plants and has the following characteristics:

1) the program is simple to understand and has low computational cost;

2)one can obtain an exact necessary and sufficient solution for the problem;

3) the implementation of the program in MATLAB language is widely used in teaching and research of automatic control systems;

4) the program uses only the MATLAB Control Systems Toolbox; thus, the program can run as a new function for the Routh criterion in the MATLAB Control System Toolbox;

5) the user has the option to see all steps of the method, improving student comprehension of this subject;

6) the program is available on the Internet;

7) the method and the program also allow the user to specify a decay rate , which is related with the settling time of the system;

8) the method and the program are also extended for proportionalintegral (PI), proportional-derivative (PD), and PID controllers, which are the most widely used in industrial processes.

Many research and applications of the Routh-Hurwitz criterion are available in the literature , but after an exhaustive search one can conclude that the proposed method and its implementation are original.

ROUTH'S ARRAY

row n	s^n	$a_{n1}(k) = \frac{p_{n1}(k)}{q_n(k)}$	$a_{n2}(k) = \frac{p_{n2}(k)}{q_n(k)}$	$a_{n3}(k) = \frac{p_{n3}(k)}{q_n(k)}$	$\cdots$
row $(n-1)$	s^{n-1}	$a_{(n-1)1}(k) = \frac{p_{(n-1)1}(k)}{q_{(n-1)}(k)}$	$a_{(n-1)2}(k) = \frac{p_{(n-1)2}(k)}{q_{(n-1)}(k)}$	$a_{(n-1)3}(k) = \frac{p_{(n-1)3}(k)}{q_{(n-1)}(k)}$	$\cdots$
$\vdots$	$\vdots$	$\vdots$	$\vdots$		
row 2	s^2	$a_{21}(k) = \frac{p_{21}(k)}{q_2(k)}$	$a_{22}(k) = \frac{p_{22}(k)}{q_2(k)}$		
row 1	s^1	$a_{11}(k) = \frac{p_{11}(k)}{q_1(k)}$			
row 0	s^0	$a_{01}(k) = \frac{p_{01}(k)}{q_0(k)}$			

FUNDAMENTALS OF FUZZY LOGIC CONTROL –

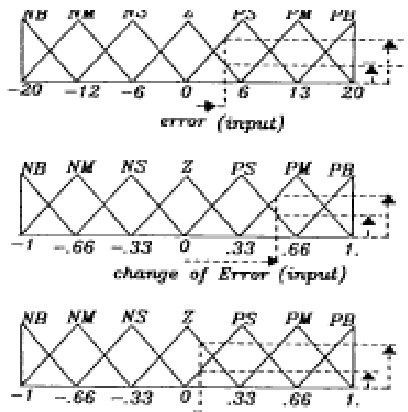
Fuzzy logic control is a new addition to control theory. Its design philosophy deviates from all the previous methods by accommodating expert knowledge in controller design. Fuzzy logic control is derived from fuzzy set theory introduced by Zadeh in 1965 . In fuzzy set theory, the transition between membership and nonmembership can be gradual. Therefore, boundaries of fuzzy sets can be vague and ambiguous, making it useful for approximate systems. FLC's are an attractive choice when precise mathematical formulations are not possible. Other advantages of FLC are:

1) it can work with less precise inputs;

2) it doesn't need fast processors;

3) it needs less data storage in the form of membership functions and rules than conventional look up table for nonlinear controllers;

4) it is more robust than other nonlinear controllers.



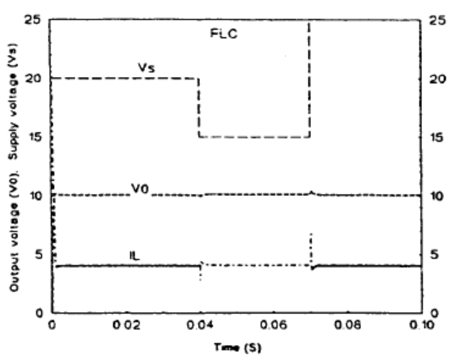
Degree of membership

PROPORTIONAL-INTEGRAL (PI) CONTROLLER –

PI controllers have been in use for the last few decades. They perform satisfactorily during transient under limited operating range. Also steady state performance is excellent. Implementation in analog or digital hardware is inexpensiveand straight forward. Since the PI controller is based on a linear model, response for large signal disturbance is poor. As shown in Fig 9, the gains and are constants and they are fine tuned for specific operating condition. Fig. 10 shows the regulated voltage response for load variation of 2.5 to 5 to 2.5 Regulated voltage shows small overshoot and under damped oscillation. Fig. 11 shows the regulated voltage response for supply voltage variation of 20 V to 15 V to 25 V. Regulated voltage shows appreciable overshoot and it settles down slowly compared to FLC.

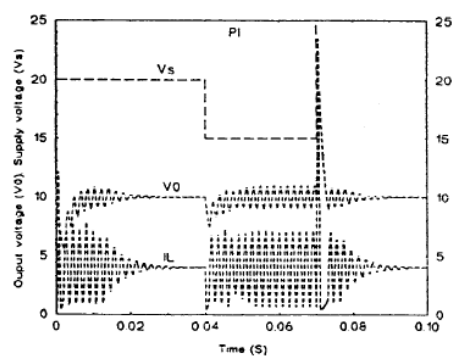
SLIDDING MODE CONTROLLER (SLMC) –

In recent times, the SLMC has shown the potential to be insensitive to parameter variations and external disturbances. A closed-loop control system using SLMC is shown infig .In SLMC, the system response in the phase plane is forced to follow a sliding line as shown in Fig. , denotes the state error which needs to be driven to zero and is its derivative. In the time domain, the corresponding response is exponential. This response depends only on the slope of the sliding line x+cx'=0 .shows the regulated voltage response for load variation of 2.5Ω to 5 Ωto 2.5Ω . Regulated voltage shows very small overshoot and settles down in a highly damped mode. But it has a steady state error. Fig. shows the regulated voltage response for supply voltage variation of 20 V to 15 V to 25 V. Regulated voltage shows small overshoot and it settles down quickly to a steady state with a steady-state.



FLC respose for supply disturbance

Vo=10V

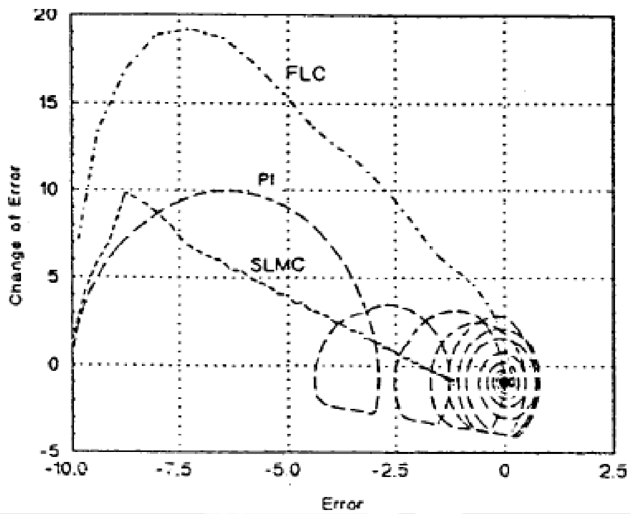


PI respose for supply disturbance

Vo=10V

SIMILARITY BETWEEN FLC AND SLMC -

Fig. 15 shows the phase plane startup response of FLC, SLMC, and PI. Both FLC and SLMC have a similar trajectory with different slope. In SLMC, the slope could be chosen as a design parameter. In FLC, the slope of the sliding line is decided by definition of linguistic variables (membership functions). There is no straightforward method to choose linguistic variables to have a required time constant. In the case of FLC, the sliding line is not linear as it is in the case of SLMC.



FLC, PI and SLMC phase plane trajectory for startup.

CONCLUSIONS -

The study of fuzzy logic control, PI control, and SLMC suggest that FLC performs satisfactorily in regulating the output during external disturbances. The transient overshoot in FLC is negligible compared to PI response. The control law employed in SLMC inherently has steady-state error due to PD type of feedback. PI shows under damped response during disturbances due to off-tuned gain constants. FLC shows sliding-mode characteristics of SLMC. From the present study, FLC seems to be a viable controller for application in power electronic systems.

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