Iterative feedback tuning method for PID controller

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***Abstract*— Many control objectives can be expressed in terms of a criterion function. Generally, explicit solutions to such optimization problem require full knowledge of the plant and disturbances and complete freedom in the complexity of the controller. In practice, the plant and the disturbances are seldom known, and it is often desirable to achieve the best possible performance with a controller of prescribed complexity such as for example a PID controller[1]. The optimization of such control performance criterion typically requires iterative gradient-based minimization procedures. The major stumbling block for the solution of this optimal control problem is the computation of the gradient of the criterion function with respect to the controller parameters: it is a fairly complicated function of the plant and disturbance dynamics.[] When these are unknown, it is not clear how this gradient can be computed. Iterative Feedback Tuning (IFT) is an input output data-based design method for the tuning of restricted complexity controllers. It does not depend on the plant model, utilizes I/O data only. This is proved by simulations.**

***Keywords*— Auto tuning, IFT method, Optimization, Set point, Settling Time**

I. Introduction

Hjalmarsson et al. (1994, 1998) developed the theory of Iterative Feedback Tuning (IFT), a technique inspired by iterative identification and control schemes[8]. It is entirely driven by closed-loop data obtained on the actual closed-loop system operating under a sequence of controllers[21]. The iterative identification and control design scheme may be considered as a parameter optimization problem in which the optimization is carried directly on the controller parameters, thereby abandoning the need of identification of a model altogether.[3]

II. Problem Formation on PID for IFT Tuning

Fig. 1 describes the basic formation of PID Controller. In this paper we are addressing this issue using Iterative Feedback Method.

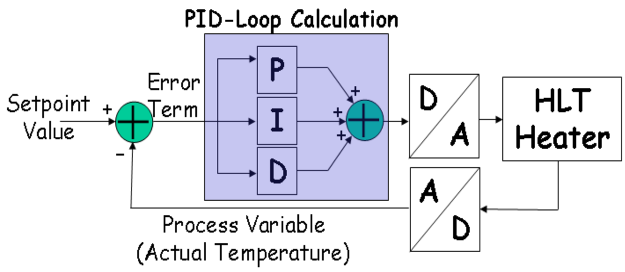


Figure 1 : Basic Diagram of PID Controller

III. Main Objectives of Auto Tuning

1. The system responds quickly to errors.

2. The system remains stable (PV does not oscillate around the SP).

3. To have a smoother response.

4. To fulfill common control design requests such as minimizing the settling time, minimizing overshoot, minimizing the control effort.

IV. Different Methods Available for Tuning

1. Ziegler & Nichols with Step Identification [ZN(OL)]
2. Internal Model Control [IMC]
3. Ziegler & Nichols with Relay Identification [ZN(CL)]
4. Iterative feedback tuning

V. Iterative Feedback Tuning

Iterative Feedback Tuning (IFT) is a model free technique for tuning the parameters of a fixed structure controller. The facts that no model is needed and that the method works with closed loop data. Iterative Feedback Tuning (IFT) is used for tuning PID controllers for the case when it is of interest to reach a new set point level as quickly as possible. The control design objective for some controller of fixed structure parameterized by *p* can be naturally formulated as a minimization of some norm of *~y(p) and control effort u(p) over* the controller parameters. We will use the following quadratic criterion:[13]

$$j(p) = \frac{1}{2N} E\left[\sum_{t=1}^{N}\left(L_Y \tilde{Y}_T(P)\right)^2 + \gamma \sum_{T=1}^{N}\left(L_U \tilde{U}_T(P)\right)^2\right]$$

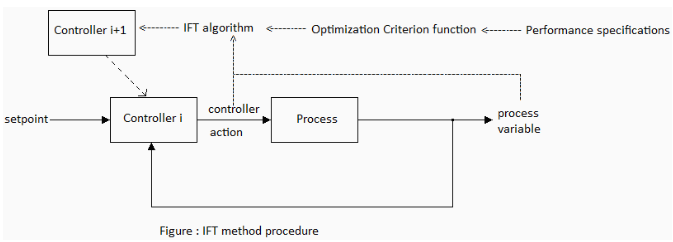
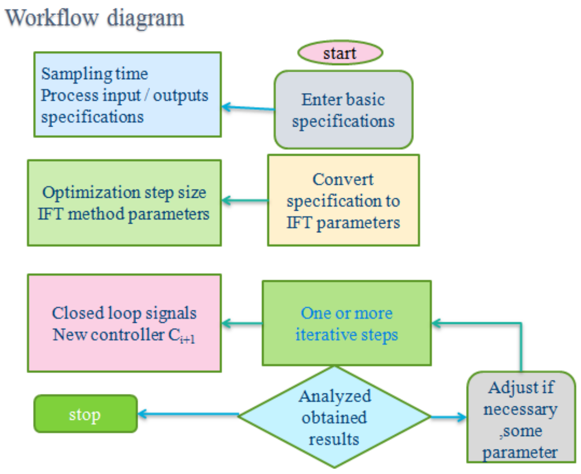


Figure 2 : IFT Algorithm

VI. WORK FLOW DIAGRAM



VII. PROPOSED ALGORITHM FOR THE ITERATIVE FEEDBACK TUNING

1. *Choose initial parameter for [Kp ki Kd] i.e for C and I = 0*
2. *Perform the closed loop experiments*
3. *Evaluate gradients for output, input and cost function*
4. *Choose and evaluate R by S.D , N.R OR G.N METHOD*
5. *Iterative controller* $p_{i+1} = p_i - y_i * R_i^{-1*} J_i$
6. *Implement the* C_{i+1} *and check the performance.*
7. *If it is found satisfactory then stop. otherwise repeat the process from step 3*

VIII. SPECIFICATION FOR IFT METHOD

- Structure of the optimized controller (PI,PID).
- Initial controller coefficients
- Sampling time of the controller
- Desired tracking performance (rising time, overshoot,..)
- Reference signal (set point) description
  IFT method parameters:
- Number of maximum iterations
- Actual step size of optimization
- Actual matrix Ri
- Scaling filters Ly , Lul
- Optimization result:
- new computed controller c_{i+1}
- Closed loop response obtained in the course of iteration step
- Estimated responses for closed loop with the new controller (closed loop sensitivities, step response)

Simulink files created:

Contents	**Autotuner PID Toolkit function list**
Autogui	Matlab S-function for making a simple PID GUI
bodePIDcompare	Comparison of Bode Diagrams with different autotuning methods
Butterdesign	Butterworth analog low pass filter design
Envgui	Matlab S-function for making a simple env PID GUI
Idareas	Identification of a FOPDT model using the method of the areas
pid_autotuner	Supervisor of a PID auto tuner (implemented as a Matlab S-function)
pid_isatd	Discrete time ISA-PID (implemented as a Matlab S-function)
pid_structure	Structure selection for a ISA-PID regulator
pid_tuning	Tune the parameters of a ISA-PID regulator with some well-defined auto tuning methods
stepPIDcompare	Comparison of step response on set point and load disturbance
autotunerPID.mdl	Simulink model of the control system
steppidsupport.mdl	Simulink model supporting step PID compare

IX. PID CONTROLLER TUNING SIMULATION

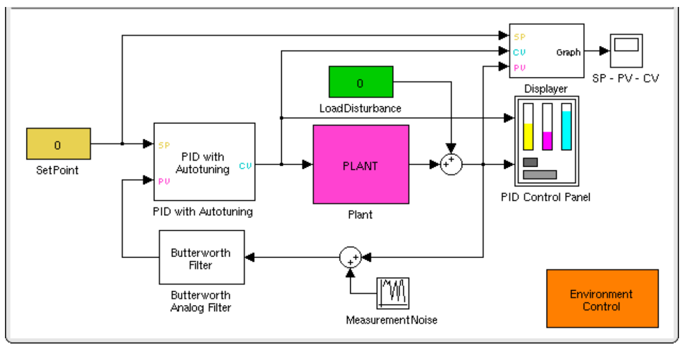


Figure 3 : simulation of PID auto tuning

Figure made up of the different s function block and user defined GUI which represents the process of simulation for IFT method. In plant transfer function of the plant added, set point set by set point block and the response of whole tuning system can be seen on graph simulation. PID with auto tuning utilizes IMC, ZN and IFT methods which can be selected by control panel of the PID controller. You can also select different identification method. Other than IFT other methods tune parameter in one iteration while in IFT iteration takes 20-50 iteration .All result are shown in result session.

PID Control Panel:

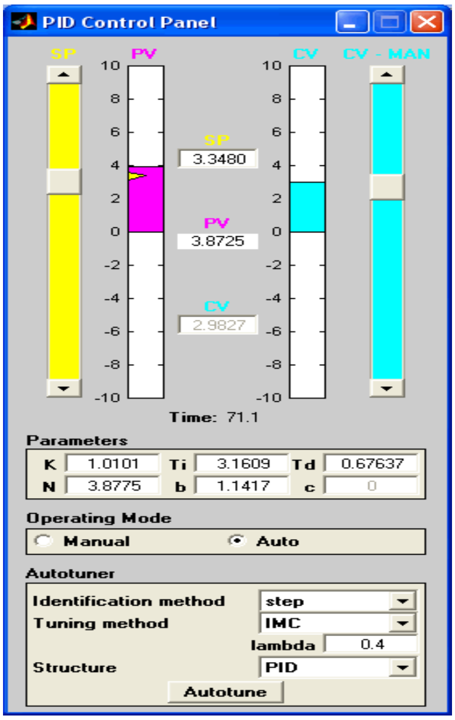


Figure 4 : PID CONTROL PANEL

RESULT SESSION :

Result Comparison with other classical method:

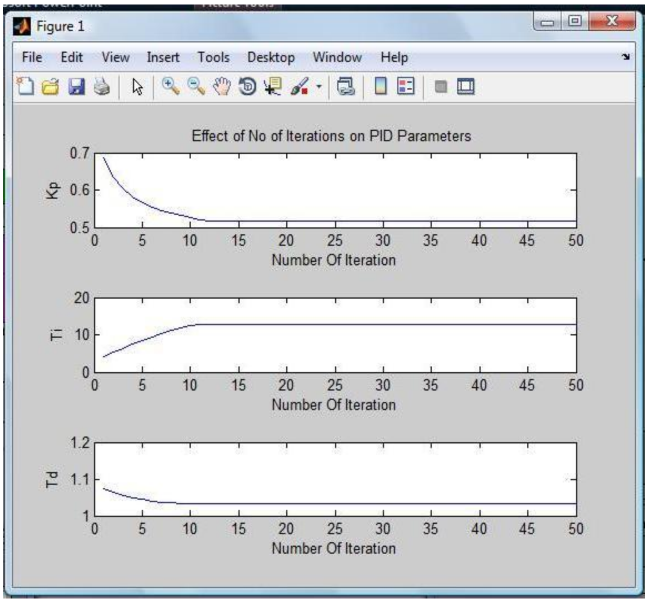
for Plant : (1-5s)/(1+10s)(1+20s)

CONTROLLER PARAMETER	ZN (OL) METHOD	ZN(CL) METHOD	IMC METHOD	IFT METHOD
P	3.53	3.53	3.39	3.03
I	16.8	28.7	31.6	46.2
D	4.2	4.2	3.9	6.08

Performance and Robustness

CONTROLLER PARAMETER	ZN (OL) METHOD	ZN(CL) METHOD	IMC METHOD	IFT METHOD
Rise time	6.43	7.3	9.1	11.2
Settling time	61.2	56.3	54.2	48.5
% over shoot	39.8	29.8	23.8	0.287
Control loop stability	stable	stable	Stable	stable

Fig 5 :Simulation Results Graph of IFT TUNING:



After 10 -15 iteration it will give nearby results.

Figure 6 :Step Response Comparison:

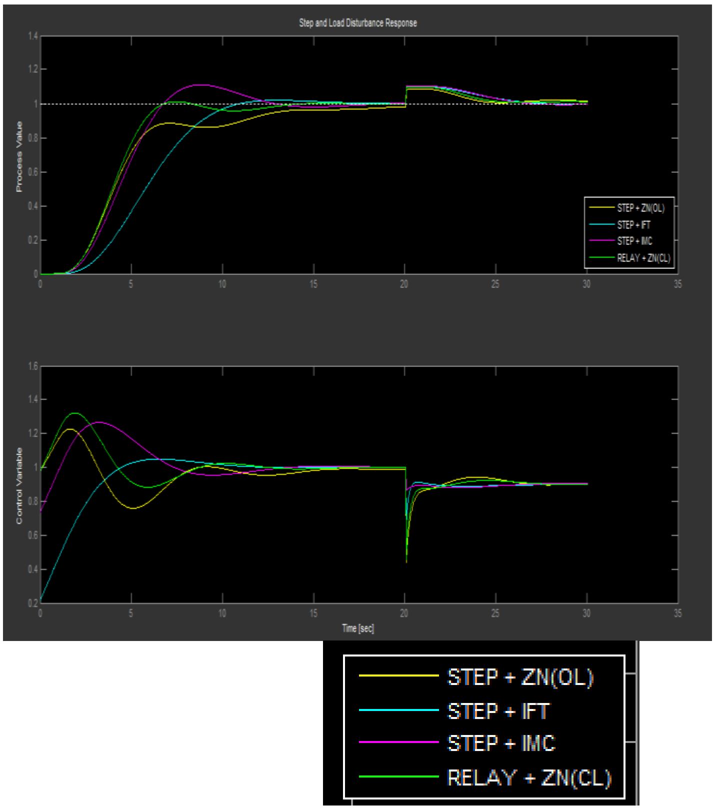
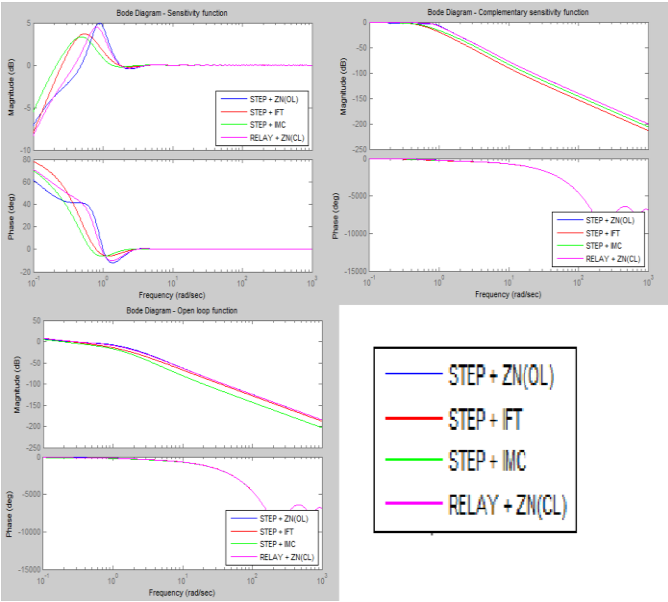


Figure 7 : Frequency domain response:



Figures shows the bode diagram for sensitivity function ,complementary sensitivity function and open loop function.

X. CONCLUSION

This Algorithm is well suited for PID loops, but it is by no means limited to the tuning of such simple controller.

Function block implementing this methodology was created. It was tested in the Simulink environment and also on a real system. Results of these experiments show the promising capabilities of this optimization technique.

From a practical viewpoint, the scheme offers several advantages. It is straightforward to apply. It is possible to control the rate of change of the controller in each iteration. The objective can be manipulated between iterations in order to tighten or loosen performance requirements. Certain frequency regions can be emphasized if desired.

The IFT method typically requires more data than other available model-free methods for tuning of PID controllers .

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