CONTROLLER SELECTION AND SENSITIVITY CHECK ON THE BASIS OF PERFORMANCE INDEX CALCULATION

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Abstract: Performance index (ISE, IAE, ITAE) of a system is a parameter on the basis of which we can decide the system accuracy and sensitivity. Hence on the basis of this we can decide that which performance index calculation will be most useful and suitable to our requirement for designing a controller. Cost of controller is associated with sensitivity hence decision on controller selection for different process may also be taken on the basis of Performance index response of controller. In this paper performance Index of the compensated systems are evaluated in MATLAB simulation.

Keywords: Performance Index, Integral of square error, Integral of Absolute error, Integral of Time Absolute error, controller (P, I, D, PI, PD, PID).

I. INTRODUCTION

The design of a control system is an attempt to meet a set of specifications which define the overall performance of the system in terms of certain measurable quantities. A number of performance measures have been introduced so far in respect of dynamic response to step input as Damping ratio, Rise time, Peak time, Settling time, Maximum overshoot etc. and the steady state error to both step and higher order inputs. To design a specific control system one should must check above specification which is not only a time consuming and complex procedure but also becomes a trial and error procedure. In Adaptive Control System where input and operational conditions are continuously varying check for system with common parameters is very difficult. Performance index based analysis is most suitable for Adaptive control system as well as normal higher order control system as it is a function of the variable system parameters and having a most desirable feature of selectivity which clearly distinguish between an optimum and non-optimum System, sensitivity for parameter variation, and ease of its analytical computation. In this paper Section [I] contains the basic performance index information and results of calculation for first order system with various controllers. Section [II] contains the MATLAB simulation result for first order system with various controllers. Section [III] contains the comparison table of performance index Vs sensitivity as well as cost.

SECTION [I]
The common Performance indices are used in practice is as below,

1) Integral Square Error (ISE)
ISE=\int e^2(t)dt

2) Integral of the absolute magnitude of error (IAE)
IAE=\int |e(t)|dt

3) Integral Time-absolute error (ITAE)
ITAE=\int t. |e(t)|dt

4) Integral Time-Square error (ITSE)
ITSE=\int t^2. |e(t)|dt

Here e(t) is the error response of a system. Generally limit of integration is from 0 to ∞ but integration up to infinity is not practical and hence limit is replaced by T which is chosen sufficiently large so that e(t) for t>T is negligible. In this paper T= 4s has been taken. ITSE is somewhat less sensitive and not comfortably computationally, hence not included in this paper. First order system 1/(s+1) for P, I and D controllers and 1/(s+2) for PI,PD and PID controller with Kp=Ki=Kd=1 has been taken for Performance index calculation. Same method can be implemented for higher order system Performance index calculation. Value of controller constants will affect only magnitude of individual Performance index graph trajectory but not its shape.

Fig.1, First order system with Proportional controller

Result of performance index with different controllers obtained by mathematical analysis and are as below,

1) D-controller
ISE: \[-0.25e^{-4}+2e^{-0.5t}\]
IAE: \[t+e^{-0.5t}\]
ITAE: \[0.5t^2+2e^{-0.5t}+te^{-0.5t}\]

2) I-Controller
ISE: \[-0.18e^{-3.5t}+0.145e^{-3.5t}\cos(1.72t)\]
Controller Selection And Sensitivity Check On The Basis Of Performance Index Calculation

-0.073e^{-3.6} \sin(1.72t) \quad (iv)

IAE:
-0.518e^{-1.8} \sin(0.86t)-0.249e^{-1.8} \cos(0.86t) \quad (v)

ITAE:
0.447e^{-1.8} \sin(0.86t)-0.216e^{-1.8} \cos(0.86t)-0.154e^{-1.8} \sin(0.86t)-0.192e^{-1.8} \cos(0.86t) \quad (vi)

3) **P-Controller**

**ISE:**
0.25t-0.0625e^{-4t}-e^{-2t} \quad (vii)

**IAE:**
0.5t-0.25e^{-2t} \quad (viii)

**ITAE:**
-0.5te^{-1.8} \sin(0.86t)-0.216t \quad (ix)

4) **PD-Controller**

**ISE:**
0.44t-0.009e-3t+0.148e-1.5t \quad (x)

**IAE:**
0.66t+0.11e^{-1.5} \quad (xi)

**ITAE:**
0.33t^2+0.22te^{-1.5t}+0.07e^{-1.5t} \quad (xii)

5) **PID-Controller**

**ISE:**
-2.25e^{-1}-0.5e^{-2t}+2e^{-1.5} \quad (xiii)

**IAE:**
-3e^{-0.5t}+e^{-t} \quad (xiv)

**ITAE:**
te^{-t}+e^{-0.5t}-6e^{-t} \quad (xv)

6) **PI-Controller**

**ISE:**
-0.013e^{-5.24t}-0.47e^{-0.76t}+0.104e^{-3t} \quad (xvi)

**IAE:**
-0.099e^{-2.62t}+1.58e^{-0.38t} \quad (xvii)

**ITAE:**
0.099te^{-2.62t}-0.038e^{-2.62t}+1.58te^{-0.38t}+4.16e^{-0.38t} \quad (xviii)

**SECTION [II]**

MATLAB Simulation Results of Various system is obtained as below,
SECTION [III]
Performance Index analysis can be individually related with controller sensitivity (on the basis of simulation) by below table.

<table>
<thead>
<tr>
<th>Controller</th>
<th>P</th>
<th>I</th>
<th>D</th>
<th>PI</th>
<th>PD</th>
<th>PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most</td>
<td>IAE</td>
<td>ITAE</td>
<td>ITAE</td>
<td>ITAE</td>
<td>ITAE</td>
<td>ITAE</td>
</tr>
<tr>
<td>Moderate</td>
<td>ISE</td>
<td>IAE</td>
<td>IAE</td>
<td>IAE</td>
<td>IAE</td>
<td>ISE</td>
</tr>
<tr>
<td>Less</td>
<td>ITAE</td>
<td>ISE</td>
<td>IAE</td>
<td>ISE</td>
<td>IAE</td>
<td>ISE</td>
</tr>
</tbody>
</table>

Table-1, PI analysis affect on controller Sensitivity

Performance analysis can be related to cost of controller design by below table. This table is obtained on the basis of table no-1.

<table>
<thead>
<tr>
<th>Cost</th>
<th>ISE</th>
<th>IAE</th>
<th>ITAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>--</td>
<td>P</td>
<td>LDP,LPI, LPIPID</td>
</tr>
<tr>
<td>Moderate</td>
<td>P,LPI,PID</td>
<td>LPI,LPIPID</td>
<td>PID</td>
</tr>
<tr>
<td>Less</td>
<td>LPI,LPIPID</td>
<td>D,PID</td>
<td>P</td>
</tr>
</tbody>
</table>

Table-2, PI analysis affect on controller Sensitivity

Tabel-1 data has obtained from the analysis of MATAB simulation of Section-[II]. In Table-1 Sensitivity of PD and PID controller becomes high after approximately 1.25 second and 0.5 seconds respectively. From above tables if we want to design a PID controller then ITAE Performance Index analysis will result highly sensitive(Table-1) and high cost (Table-2) controller, ISE Performance Index analysis will result moderate sensitive (Table-1) and moderate cost (Table-2) controller and IAE Performance Index analysis will result less/poor sensitive (Table-1) and less cost /cheap (Table-2) controller.

CONCLUSION
Controllers are generally selected on the basis of our specific requirements. Analysis of this paper on first order system with various controller shows that, design of controller particularly with respect to sensitivity can be easily predicted by performance index analysis. Hence with respect to sensitivity Performance Index analysis may be used as standard for controller design. Cost and sensitivity of controller closely related to each other, hence again Performance index analysis may play an important role in cost estimation (High, Moderate or Low) of controller. The same method can be checked for higher order systems and can be implemented for dead time and other important control system analysis.

REFERENCES