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Robust Control of Steam Turbine System Speed Using Improved IMC Tuned PID Controller

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Abstract

This paper explains the method of obtaining proportional, integral and derivative (PID) parameters for single loop control of turbine speed control system by approximating the feedback form of an IMC controller with elimination of higher order terms in the controller form to classical PID form for robust operation. The IMC has single tuning parameter to adjust the performance and robustness of the controller. The proposed method is the efficient in set-point tracking and disturbance rejection and controlling the overshoot, stability and dynamics of the speed control of turbine. The results obtained in simulated environment implemented in LabVIEW show the improvement in the performance compared to PID tuning using conventional techniques like Ziegler-Nichols (Z-N) rules and tuning technique proposed by Y. Lee et al.

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1. Introduction

The PID controller finds widespread use in the process industries, and it is the most common form of feedback in process control systems. A great deal of effort has been directed at finding the best choices for controller gain, integral and derivative time constants for various process models\cite{1}. Among the performance criteria used for PID controller parameter tuning, the criterion to keep the controlled variable response close to the desired closed-loop response has gained wide spread acceptance in the process industries because of its simplicity, robustness, and successful practical applications\cite{2}.

The selection of the controller parameters is an optimization problem in which the designer of the process control system attempts to satisfy some criterion of optimality, the result of which is often referred to as a
good control [13]. The process of tuning can vary from a trial and error attempt to find suitable control parameters for good control to an elaborate optimization calculation based on a model of the process and a specific criterion for optimal control. A typical criterion for good control is that the response of the system to a step change in set point or load should have minimum overshoot, minimum rise time and minimum settling time [3, 9].

This paper focuses on the model that makes up the steam turbine and the hydraulic governor (control valve) to control the speed of the turbine. In refineries, steam turbine is considered as the heart of the plant, as large number of high capacity compressors run on steam turbines. This makes the control and the tuning optimization of steam turbines significant.

In refineries, chemical plants and other industries the gas turbine is well known tool to drive compressors, which are of centrifugal type. These consume much power, as they handle large volume flows. The combination of gas turbine and compressor is highly reliable, and they play significant role in the operation of the plants [4].

Fig.1 shows the setup of high-pressure steam (HPS) used to drive the turbine, which in turn drives the compressor. The control valve is used to control the amount of steam going to the turbine. The typical control mechanism used to control the steam flow is PID.

This paper examines the performance of the proposed method, which involves elimination of higher order terms in obtained controller form to the classical PID form with PID controller tuned using Zeigler-Nicholas technique and the tuning technique proposed Y. Lee et.al.

![Diagram of Turbine speed control system](image1)

![Diagram of IMC Structure](image2)

2. IMC Controller

Garcia and Morari introduced internal model control (IMC). IMC is characterized as a controller where the process model is explicitly an internal part of the controller. This method is based on an accurate model of the process and leads to the design of control system that is stable and robust [5, 11]. A robust control system is one that maintains satisfactory control in spite of changes in dynamics of the process. The block diagram of an IMC system shown in Fig. 2.

The robustness is improved by adding a low pass filter \( G_f(s) \), which attenuates the effects of process model mismatch, which usually occurs at high frequency and provides good set point tracking [7, 10, 12, 13].

\[
G_f(s) = \frac{1}{(\alpha s + 1)^n}
\]

\( (1) \)

\( G_{IMC}(s) \) is obtained by first factoring the process model into invertible and non-invertible elements.
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