FRACTIONAL ORDER CONTROLLER FOR NON – LINEAR CONICAL TANK SYSTEM

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ABSTRACT

- Conical tank process is a nonlinear model. The non-linearity arises due to nonlinear parametric variation in terms of volume of the tank, the application of Conical Tank Process is in chemical industry, paper mills etc. This paper discusses a comparative study between conventional controller and fractional order controller. Mathematical linear model of the system is derived and performance improvement is shown on the application of fractional order control.

- **Keywords:** Conical Tank Process, PID, Fractional Order PID.

INTRODUCTION

- Conical tank systems are used in industrial process control and chemical industries like sewage treatment plants, sludge settling plants, colloidal mills etc., because it ensures excellent drainage of the fluid material.
- Conical tank is a nonlinear system and hence, it poses a difficult control problem. Conical tank level control is obtained by controlling inlet flow rate.

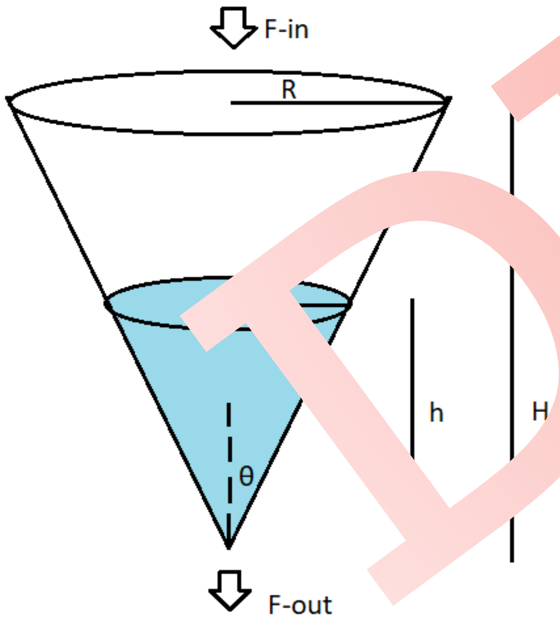
- Fractional order controllers may be employed in non-linear conical tank systems, which can improve controllability of the system.
- Fractional Order Proportional Integral Derivative (FOPID) Controllers have two degrees of freedom of powers of I and D action, which can improve system stability, reduce peak overshoot, and Integral Square error (ISE).
- In Fractional Order Control, the integer power of ‘s’ in the transfer function of the system is replaced by a fraction.
- Fractional order control is implemented using a toolbox developed in MATLAB. FOMCON toolbox developed by Aleksei Teplajekov is used in this work.

PROBLEM STATEMENT

- Conical tank systems are non-linear in nature because of its varying cross sectional area. For a conical tank system, the radius of the tank varies with vertical position of the tank. For industries using non linear processes, designing controller is a challenging task, due to aforementioned non linearity in the system.
- The aim of this project is to develop a Fractional order PID controller which can balance non-linearities in the system, as well as improve overall response of the system.

METHODOLOGY

- The process considered here is the conical tank system as shown in figure, in which liquid level is maintained at a constant rate by controlling the inflow of the tank F_{in}.



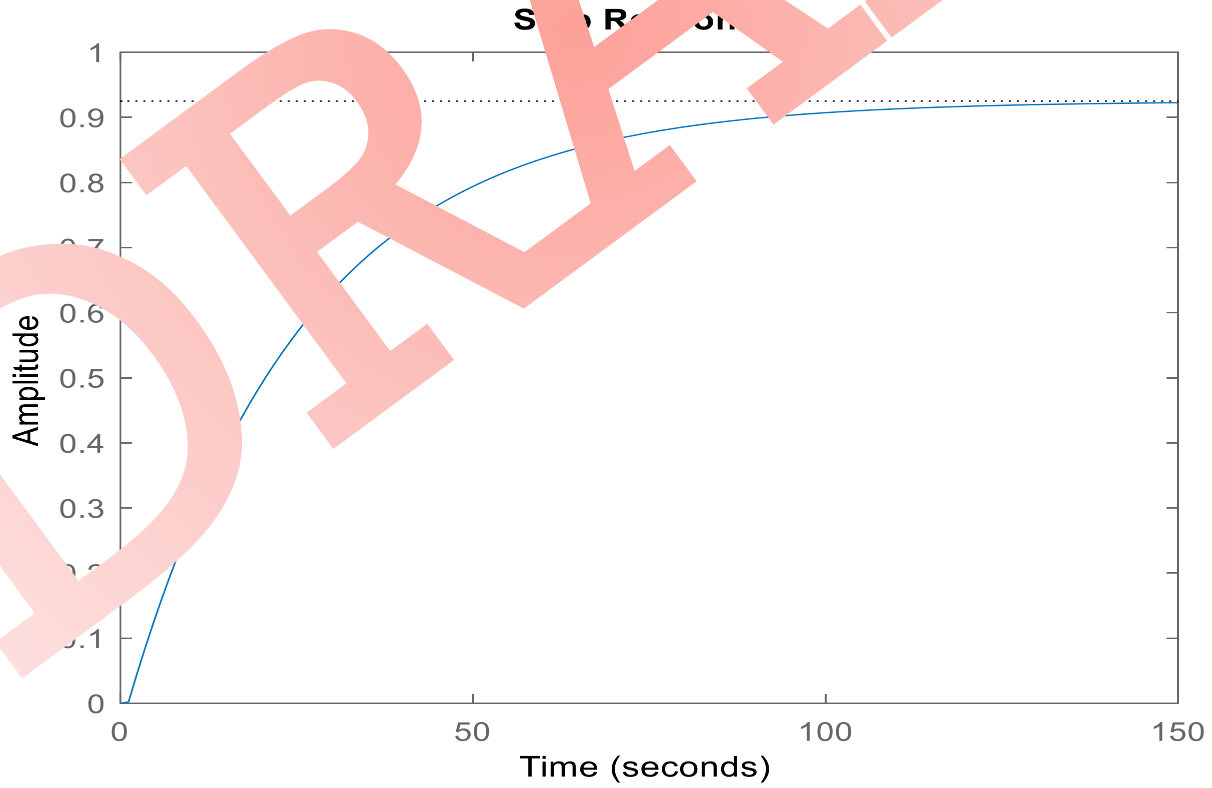
The parameters of the conical tank are defined as follows:

- H be the maximum height of the tank
- R be the radius of the liquid surface at height H
- F_{in} be the inlet flow rate
- F_{out} be the outlet flow rate
- h be the liquid level (height) at any time t
- r be the radius of the surface at a given height

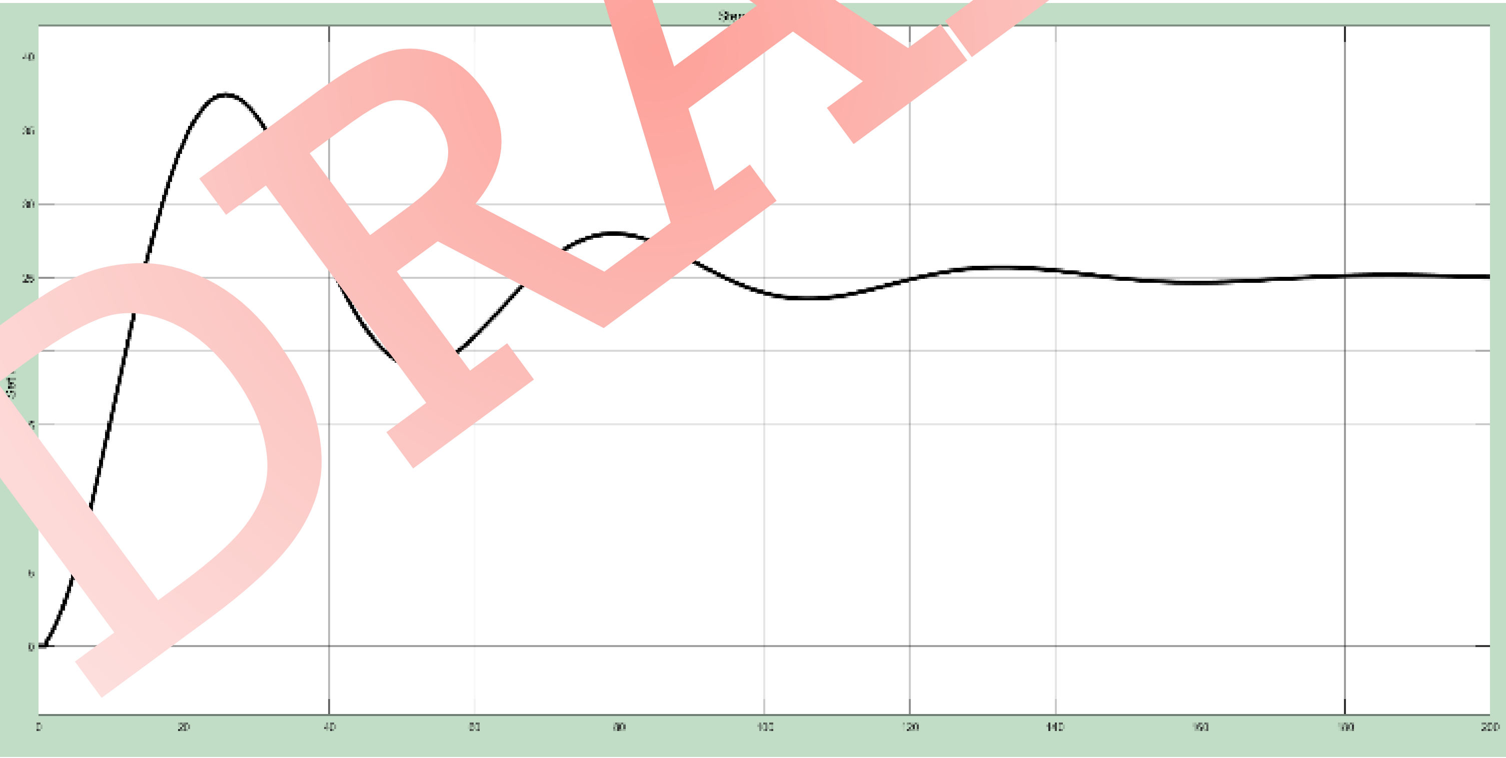
- Using Taylor series approximations, transfer function of following conical tank is modelled.

- $G(s) = \dfrac{0.925e^{-1.095s}}{25.025s+1}$

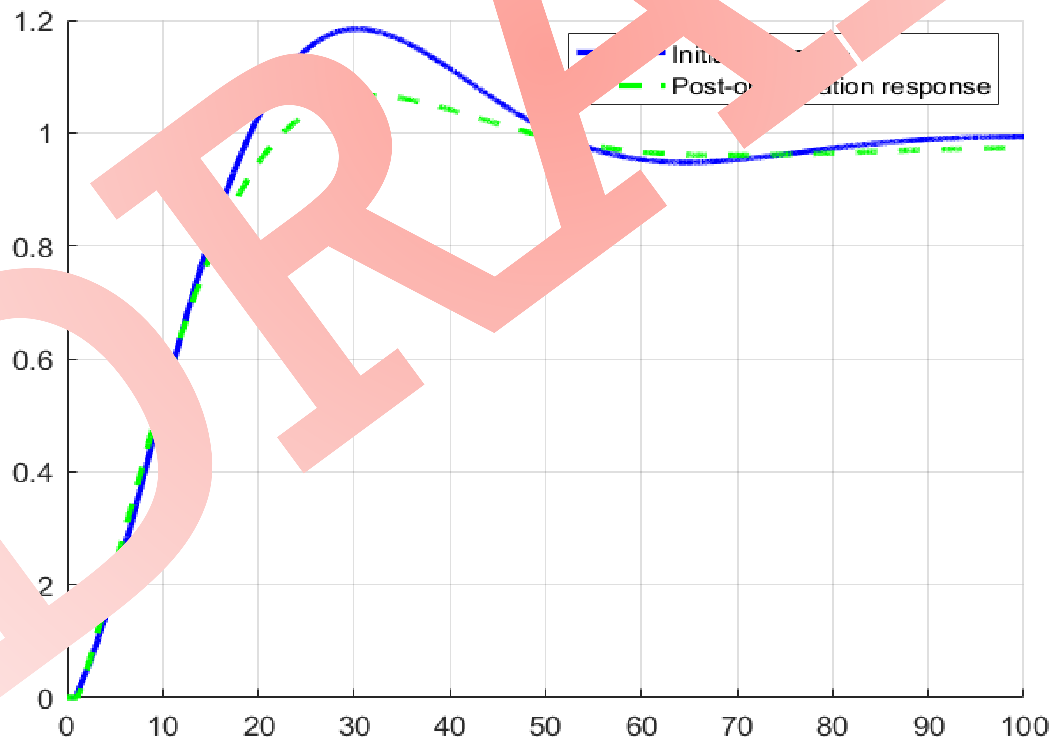
- Step response of conical tank is obtained as follows



- Conventional PID controller for the following conical tank system is modelled.
- Ziegler Nichols stability tuning method is used. Transfer function of PID controller is obtained as
- $C(s) = 0.78 + \frac{0.39}{s} + 0.37 * s$
- Step response of PID controller is obtained as follows

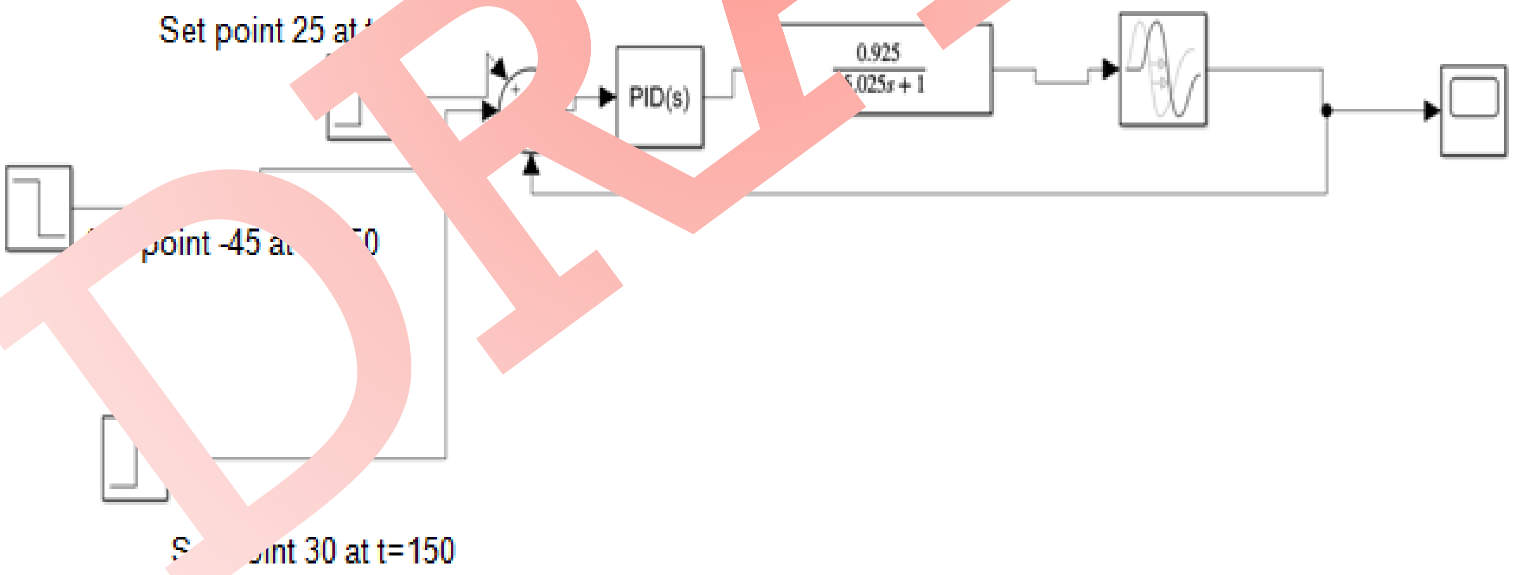


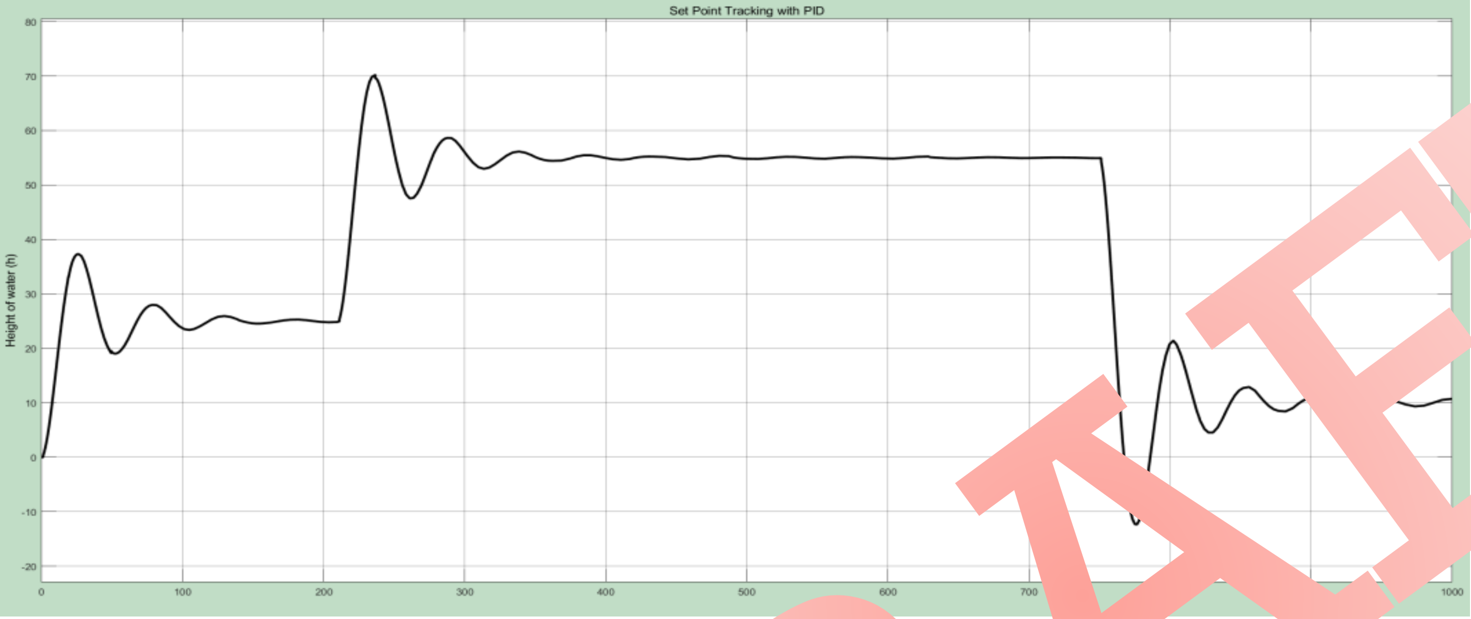
- Fractional order PID controller for the following conical tank system is modelled.
- FOMCON optimization toolbox is used for modelling FOPID controller. Transfer function of FOPID controller is obtained as,
- $C(s) = 0.78 + \frac{0.39}{s^{0.8}} + 0.37 * s^{0.1}$
- Step response of FOPID controller is obtained as follows



RESULTS

- Step response of PID and FOPID controller is compared using set point tracking.





Set point tracking with PID

Set point tracking with FOPID

Time domain indices such as Peak overshoot (M_p), Steady state error (e_{ss}), Integral Square Error (ISE) and Integral Absolute Error (IAE) are compared in following table.

Controller	IAE	ISE	Mp	T[illegible]	Ess
PID	24.[illegible]	1[illegible].53	[illegible].75%	9.75s	0dB
FOPID	31[illegible]2	7.33	8.512%	14.83s	0.018dB

CONCLUSION AND FUTURE SCOPE

- From this study, it is possible to conclude that an ISE tuned FOPID controller is able to provide a response having lower ISE and overshoot, at the cost of a slightly higher Steady state error. PID controller provides response with lower IAE and rise time, at the expense of higher overshoot.
- Improvements to controller design can be performed by including control strategies such as Model predictive control and Adaptive tuning, in order to fine tune system response. Effects of including FOPID controller tuned using neural networks and IMC tuned Fractional order PID controller, to the system can also be studied.

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PAPERS PUBLISHED

- Paper titled **“Performance Improvement of Conical Tank Process Applying Fractional Order Control”** was selected for KTU Techfest
- Paper titled **“Performance Improvement of Conical Tank Process Applying Fractional Order Control”** has been submitted for Springer conference 2020, being held at MIT Manipal
- Paper titled **“Performance Improvement of Conical Tank Process Applying Fractional Order Control”** has been prepared for upcoming ieee conference.