wjert, 2019, Vol. 5, Issue 2, 512-524. Review Article ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.218

STUDY OF APPLICATION OF FUZZY-PID DRUM LEVEL CONTROL FOR BOILER

Dr. C. Nagarajan[1], P. Johnlouis*[2], N. Balasubramaniyan[3] and M. Hari[4]

[1]Professor, Department of EEE, Muthayammal College of Engineering, Rasipuram, India.
[2,3,4]Students, Department of EEE, Muthayammal College of Engineering, Rasipuram, India.

Article Received on 06/02/2019 **Article Revised on 27/02/2019** **Article Accepted on 17/03/2019**

***Corresponding Author**
P. Johnlouis
Students, Department of EEE, Muthayammal College of Engineering, Rasipuram, India.

ABSTRACT

Boiler unit plays essential role in power plant and controlling the boiler drum level is one of the important operations. Nowadays, conventional Proportional plus Derivative plus Integral (P+I+D) control is being used for this purpose. These conventional controllers in power plants are not very stable when there are fluctuations. To overcome this and to get better solution intelligent controller (fuzzy logic) is used to tune the conventional PID controller automatically in online process through LabVIEW platform. In addition, Conventional PID and Hybrid Fuzzy-PID controllers are compared. Hybrid Fuzzy-PID controller result proves that, it offer better performance (in terms of settling time, rising time, steady state error) than conventional PID controller in boiler drum level control.

KEYWORDS: *Boiler Drum Level, Soft Computing, Hybrid Fuzzy-PID Controller*.

INTRODUCTION

In power plants boiler drum is a closed vessel in which steam is produced by burning coal in the furnace. The main input variable of the boiler drum are fuel, feed water and air. The outputs of the boiler system are electrical power, steam pressure, steam temperature and flue gas as shown in (fig.1.) According to these parameters the drum level may increase or decrease. The boiler drum level should be monitored continuously. It should be within a certain limited value. If the measurement of boiler drum level is not within the limited value, water carryover may be occurred. If the level is low in drum overheating occur in boiler water tube this cause the damages in boiler drum surface and creates the cracks in the surface.

If the value of level in boiler drums more than the limited value it may transfer the moisture into the turbine, which reduce the boiler efficiency. P.Meenu.[1] is described the boiler drum level control which is done by fuzzy logic controller. If the water level is too low in boiler drum it leads to boiler explosion. If the water level is very in boiler drum it cause damage to turbine due to the affect of separator steam water. Serious consequences occur in high or low level so we must take strict control. Conventional Proportional integral derivative controller is popular three element control. If there is any process disturbance the 3-element control does perform well due to the lack of proportional controller gain knowledge .The collected data from the PID controller is used to gain the knowledge on the intelligent control technique and developed fuzzy logic control.

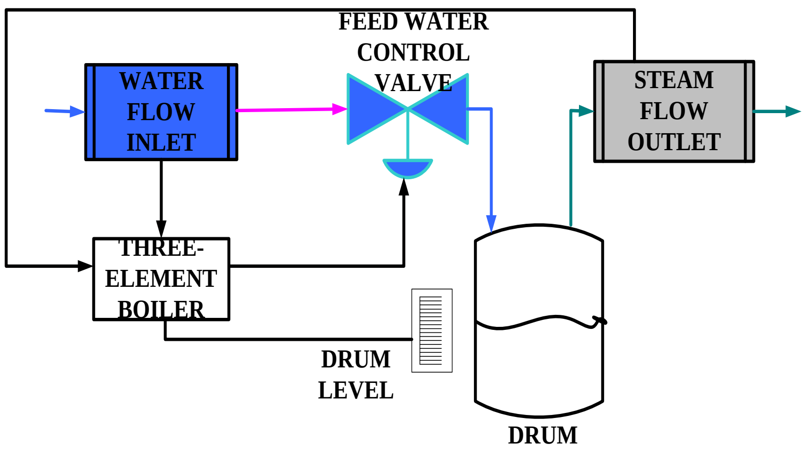


Fig. 1: Basic Block Diagram of Drum Level Control.

Nagarajan,[2] is illustrated the water in the boiler drum has a nonlinear characteristics, large time-varying, strong-coupling and multivariable. Using mathematical model of boiler drum, fuzzy control theory is designed for controlling the boiler drum level system. Both fuzzy logic and conventional logic are used in controlling the drum level. In MATLAB software verification and simulation are done and get the result of drum level system. By observing that static and dynamic characteristics of fuzzy controller is improved and also best real-time control of boiler drum level is achieved.

Madheswaran,[3] explained the boiler drum level controlling using an intelligent model. In three element boiler drum the parameters are determined using PID tuning methods like Ziegler-Nicholas method, Tyreus-Luyben method and Internal Model Control in which IMC used to tune the PID controller.

The same author describes the approach for controlling a very crucial parameter of boiler level of the boiler drum using PID controller. IMC based PID tuning method is used with feedwater and feedback strategy is used to control two element drum level. Besides also the modeling of the process for level control and implemented it in simulink. Hardware model has also been developed and proved open loop validation for theoretically derived model and practical model and simulation results. The boiler parameters are measured and controlled using embedded system through LabVIEW. Water droplet identifiers are used to check the steam dry or wet. Dry steam is required for power production, if wet steam passed to turbine it will damage and production is affect. Water droplets identifiers detect the wet steam and converted into dry steam.

Nagarajan,[6] presented the paper about the new development of the boiler-turbine coordinated control strategy using fuzzy reasoning and auto tuning techniques. Boiler-turbine system is a very complex process due to multivariable, nonlinear, slowly time-varying plant with large settling time and a lot of uncertainties. The main stream pressure control loop and power output are strongly coupled in boiler turbine unit. The automatic coordinated control of two loops is very challenging problem. The Gaussian partition a special subclass of fuzzy inference is used to self-tune the main steam pressure PID controllers.

Nagarajan[7] analyzed the work about possibilities of applying feedback linearization techniques to the non linear control of super heat steam pressure and power output of boiler-turbine generating unit. Computer simulation is used to design and evaluated the nonlinear coordinated controller. The simulation results are helps to compare the proposed strategy with conventional strategy. Improvements of nonlinear control system are observed by the results.

Same Author describes the optimize control of the boiler in multi-zone heating system by an inferential model-based predictive control scheme to save energy and to improve thermal comfort. It has only three inputs they are outside air temperature, total solar radiation falling on the exterior building and temperature of water in the boiler drum. Input-output data are collected from the portable temperature loggers to estimates the parameter for the modeling. The simulation results show that overall performance of the heating system is improved compared to the conventional boiler control scheme.

Madheswaran,[9] designed self tuned PID controller for controlling speed of PMDC motor with 49 fuzzy rules. Fuzzy rules are framed based on two fuzzy inputs "Error & Change in Error" and three fuzzy outputs such as "Proportional gain(K_p), Integral gain (K_i) & Derivative gain(K_d)".Dynamically PID Controller parameters are updated through fuzzy interference system in platform of LabVIEW.

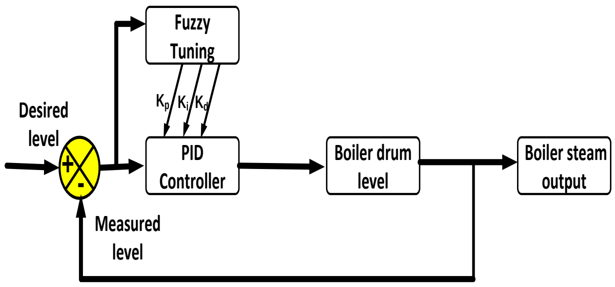


Fig. 2: Closed loop control for Boiler Drum Level Control.

The above block diagram (Fig.2.) presents the overview of proposed boiler drum level control which consists of the following one major stage. The Hybrid Fuzzy-PID with self tuning technique i.e. IF and THEN fuzzy control or rule base according to the error and change in error that used to provide necessary actions to achieve optimal response through the auto-selection of PID controller parameters.

Mathematical Modeling of Boiler Drum

The modeling of boiler drum is described based on steam drum, valve,[1] Transfer function for steam drum is described in equation (1).

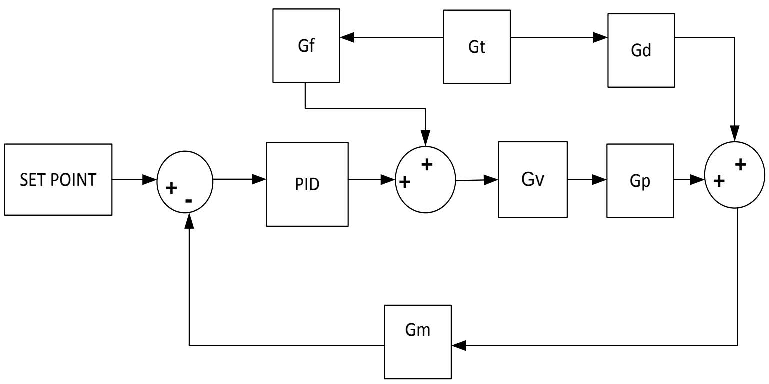


Fig. 3: Modeling Block Diagram of Boiler Drum.

$$G_p(s) = \frac{-0.25s + 0.25}{2s^2 + s} \qquad (1)$$

Transfer function for valve

$$G_{pv} = \frac{-0.25S + 0.25}{s^3 + 0.25s^2 + s} \qquad (2)$$

The equation (3) shows the series of process transfer function and valve transfer function from the (fig.3.)

$$G_{pv} = \frac{-0.25s + 0.25}{s^3 + 0.25s^2 + s} \qquad (3)$$

The transfer function of the boiler drum is:

$$G_{pv} = \frac{-0.25s + 0.25}{0.3s^3 + 2.15s^2 + s} \qquad (4)$$

Design and Implementation of Hybrid Fuzzy- PID Controller

In industrial control systems widely used controller is PID controller which is a generic feedback control loop mechanism. Error value calculated by the PID controller is the difference between a measured process variable (PV) and a desired set point (SP). In this developed system fuzzy based rule is given to the PID controller for precise and faster optimal response. It helps to achieve desired set point with minimum rise time and settling time than conventional PID controller. The Basic structure of hybrid PID controller is shown in (fig.4.)

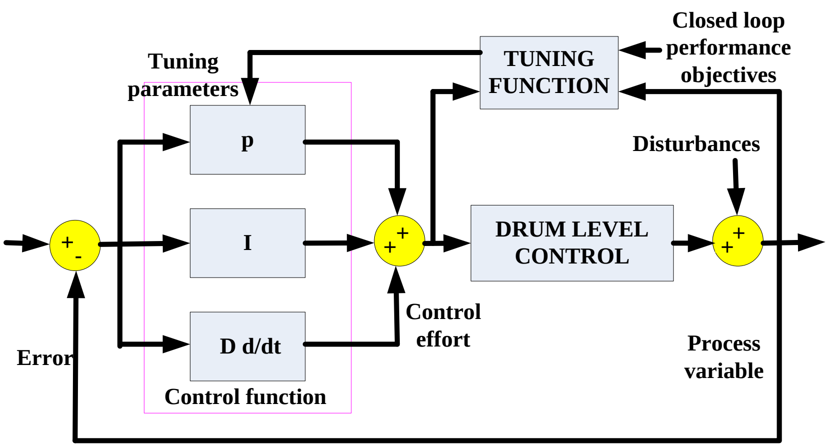


Fig. 4: Basic Block of Hybrid Fuzzy-PID Controller.

The relation between fuzzy input parameter(error and change in error) and fuzzy output parameter(K_p, K_i and K_d) are given by the Hybrid Fuzzy- PID controller which is shown in figure 5.

By the principle of fuzzy self tuning, the three parameters K_p, K_i and K_d are modified in order to achieve control actions if there is any update in error and change in error for various level as set point.

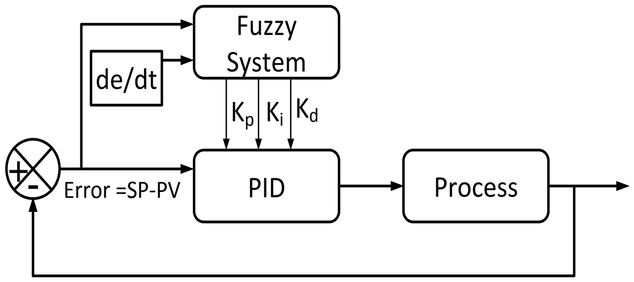
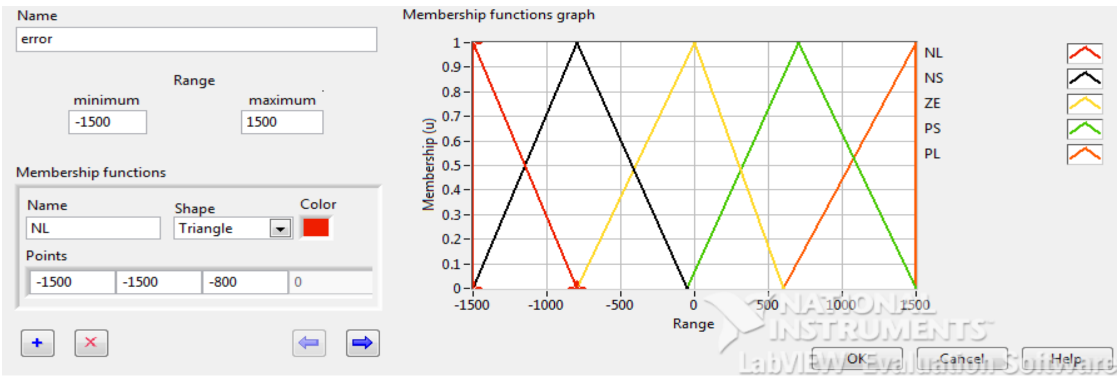
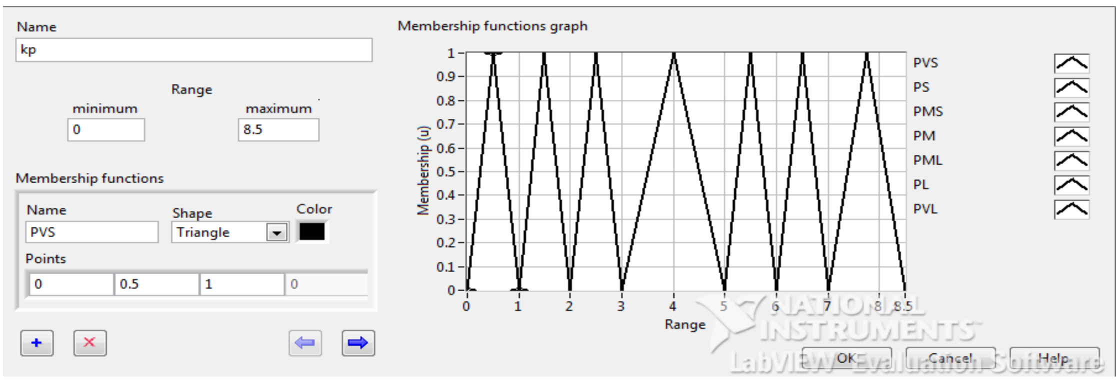


Fig. 5: Basic structure of Hybrid Fuzzy-PID.

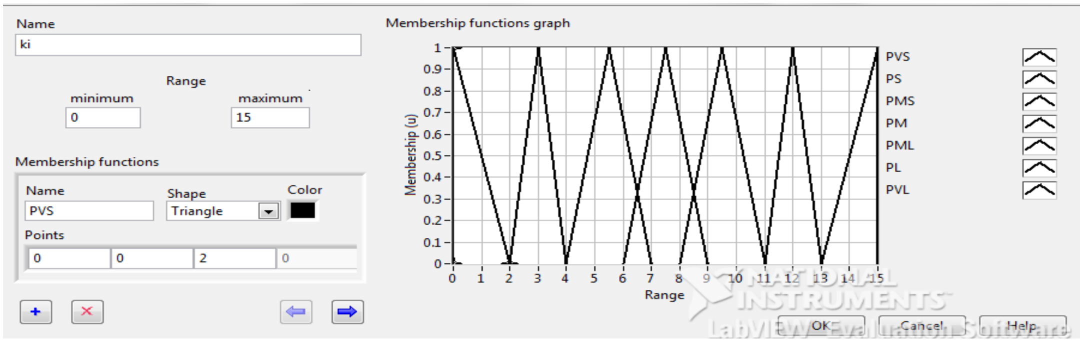
The error and change in error values are determined from previous set point values and present set point values to perform good dynamic, steady state and static performance without any disturbances. Five fuzzy labels (NL, NS, ZE, PS and PL) are framed for fuzzy input parameters such as error and change in error values which are mentioned in Table I. Similarly, six fuzzy labels (PVS, PS, PMS, PM, PL, PVL) are framed for fuzzy output parameters as represented in Table II.



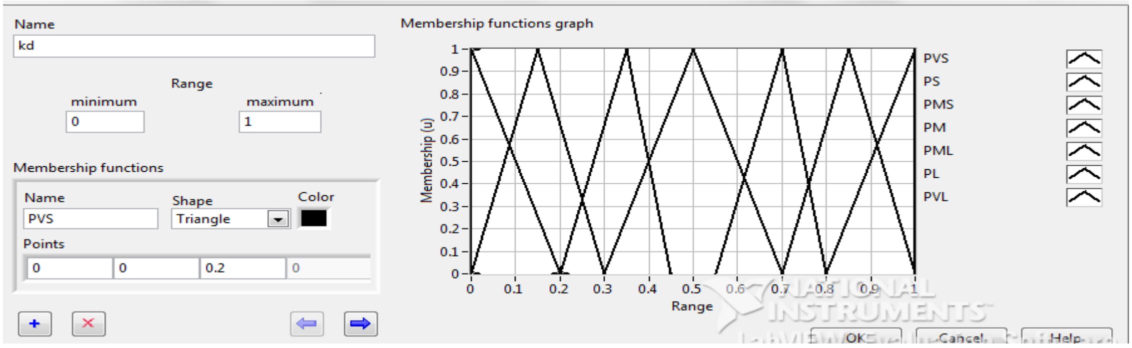
(a)



(b)



(c)



(d)

Fig. 6: Fuzzy Control of MF's (a) Error "e" (b) Change in Error "ec" (c) Proportional Gain "Kp" (d) Intregral Gain "Ki".

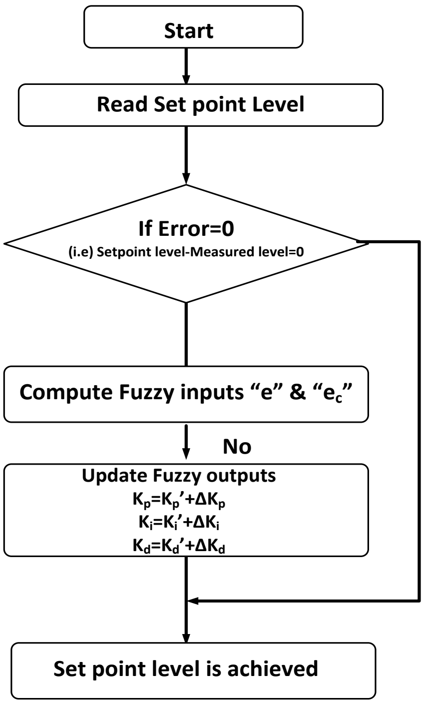


Fig. 8: Flowchart of Closed Loop Drum Level Control.

Experimental Setup

This section is described simulation of conventional PID Controller and hybrid fuzzy-PID controller action on drum level control. Conventional PID controller (existing approach) parameters are tuned by using zeiglar-nicholas tuning methodology. The proposed approach (fuzzy tuning) is achieved by trial and error method.

A. Conventional PID Controller Action on Drum Level Control

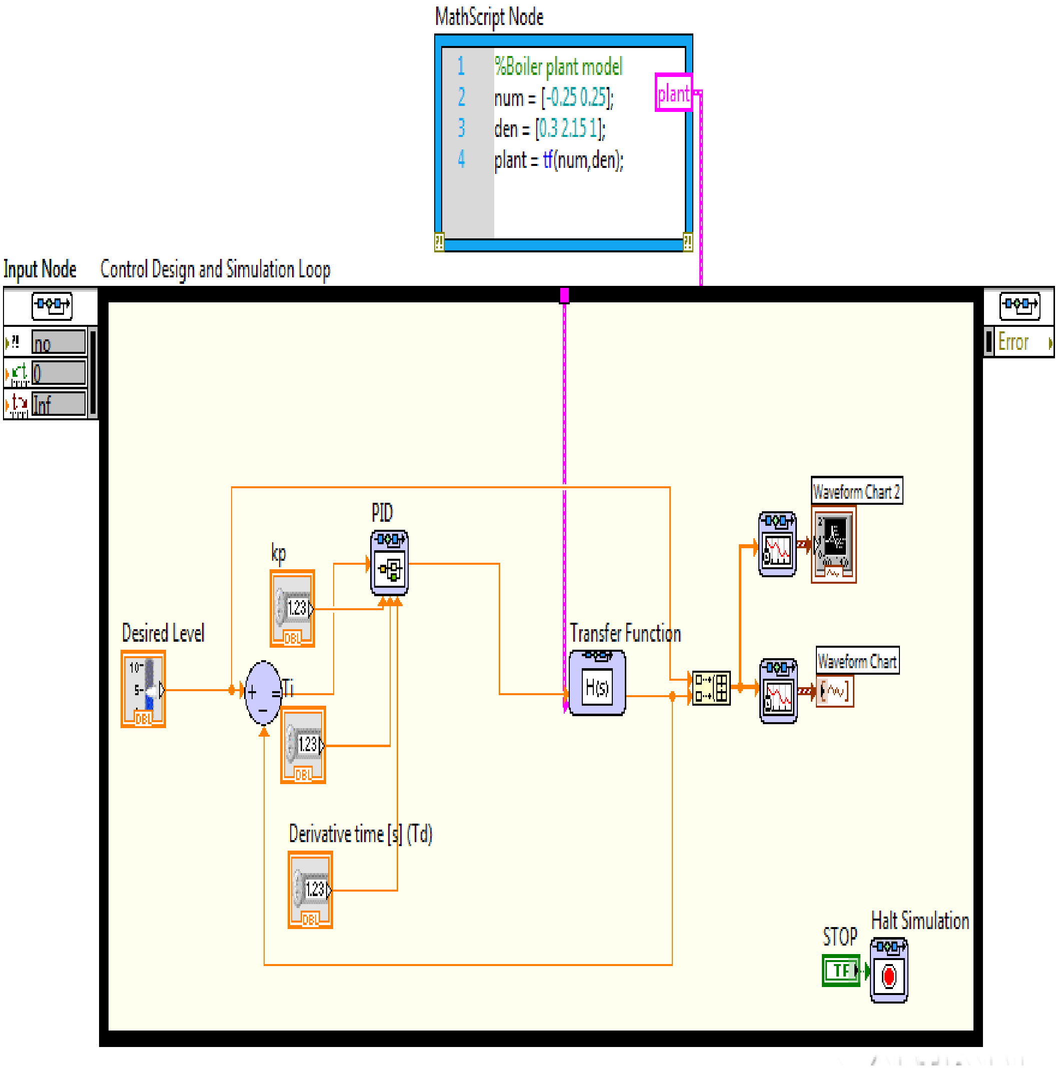
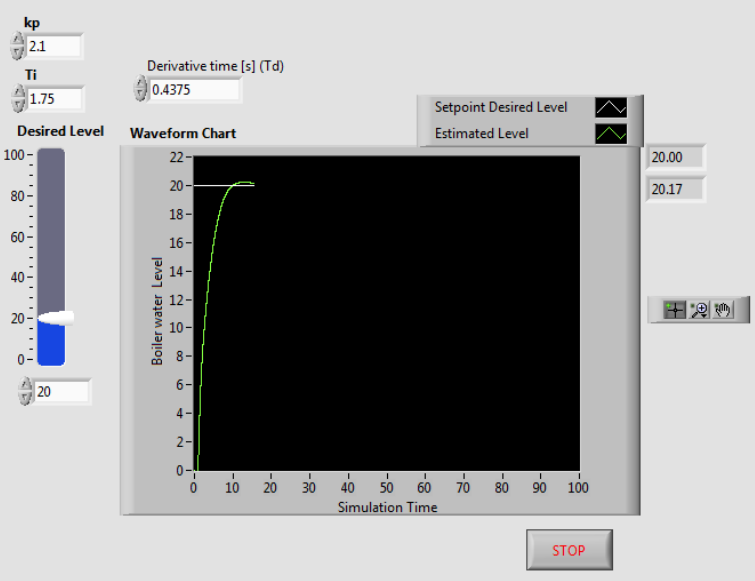


Fig. 8: Conventional PID controller simulation-Block diagram window.

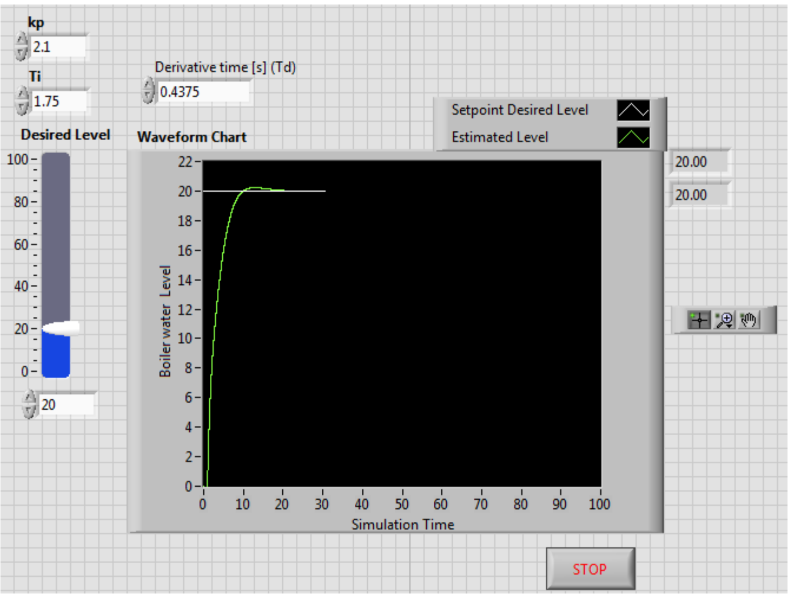
The above simulation block diagram (Fig.9.) describes the conventional PID controller based on the boiler drum level control. It consist of the transfer function of the boiler, conventional PID controller and their parameter like proportional gain K_p, integral time τ_i and derivative time τ_d.



(a)

In conventional PID controller the set point”20cm” is attained after 39 seconds. It takes more time to settled due to overshoot present in the simulation results Fig.10 (a) & (b).

The above block diagram window (Fig.11) describes the simulation block of hybrid fuzzy-PID controller based on the boiler drum level control. The simulation block is designed using boiler drum model parameters. Membership functions and rule viewer for input and output variables are available in the Fuzzy tuned controller.



(b)

Fig. 9: Simulation result of PID controller Front Panel window (a)before settling point (b)after settling point.

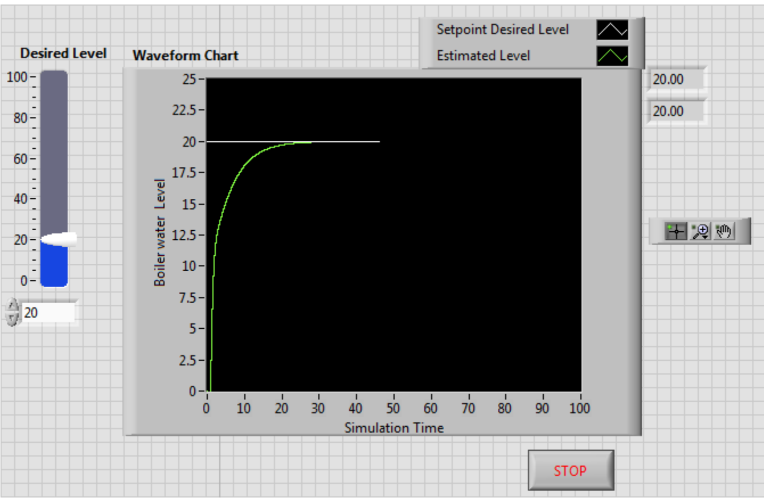


Fig. 12: Simulation results for Hybrid Fuzzy-PID controller.

In hybrid Fuzzy-PID controller simulation results there is no overshoot. Using logic rules Fuzzy controller is designed to rectify the overshoot which is occurred in the conventional PID controller. Also settling time also decreased in Hybrid Fuzzy-PID controller. Here set point "20cm" is settled at 27.5 seconds as shown in (Fig.12.)

Table III: Tentative Results Of Pid Controller Based Drum Level Control.

Set point Level	Settling time t_s (s)	Rise time t_r(s)	Steady State Error in cm
25 % of Level	39.8	10.7	1.17
50 % of Level	47.3	10.7	1.57
75 % of Level	50	10.7	1.61
100 % of Level	54	10.7	1.67

Table IV: Hybrid Fuzzy-Pid Based Drum Level Control.

Set point Level	Settling time t_s (s)	Rise time t_r (s)	Steady State Error in cm
25 % of Level	27.5	8.4	0
50 % of Level	27.4	8.6	0
75 % of Level	27.8	8.2	0
100 % of Level	27.4	8.7	0

CONCLUSION

The Conventional PID and Hybrid Fuzzy-PID Controller techniques are successfully implemented for closed loop control of Boiler drum level control system. The performances of two different controllers are analyzed by the investigation of settling time, rise time, dead time and steady state error with simulation results. From the LabVIEW Platform based simulation results, it is concluded that, the Hybrid Fuzzy-PID parameters are tuned automatically to meet the desired response and also results are short listed at various set point of the level. The Hybrid Fuzzy-PID controller offers the better performance control over the conventional PID controller. While comparing with conventional PID controller performance, Hybrid Fuzzy PID controller offers better dynamic response, shorter settling time, rise time and zero steady state error.

REFERENCES

1. P. Meenu and G.Priya “Fuzzy logic Based Boiler Drum Level Control and Production System” in *International Journal for Research and Development in Engineering*, 2014; 255-260.
2. C.Nagarajan and M.Madheswaran, ‘Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter with fuzzy controller’ - *Journal of Electrical Engineering*, 2012; 63(6): 365-372.
3. R.Raja and C.Nagarajan, “Performance Analysis of LCL-T Filter Based 2 Stage Single Phase Gird Connected Module with ANN Controller using PV Panel," *Current Signal Transduction Therapy*, 2018; 13(2): 159-167.
4. C.Nagarajan and M.Madheswaran, “Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis” *Springer, Electrical Engineering*, 2011; 93(3): 167-178.
5. E.Geetha, C. Nagarajan, “Stochastic Rule Control Algorithm Based Enlistment of Induction Motor Parameters Monitoring in IoT Applications," *Wireless Personal Communications*, 2018; 102(4): 3629–3645.
6. M.Madheswaran, C.Nagarajan, “DSP Based Fuzzy Controller for Series Parallel Resonant converter”, *Frontiers of Electrical and Electronic Engineering*, 2012; 7(4): 438-446.
7. C.Nagarajan, “Single-Stage High-Frequency Resonantac/AC Converter Using Fuzzy Logic and Artificial Neural networks’, *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 30-37.
8. E Geetha, C Nagarajan, “Induction Motor Fault Detection and Classification Using Current Signature Analysis Technique”, *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 48-52.
9. GS SatheeshKumar, C Nagarajan, ST Selvi, “A Virtual Impedance Based Analysis of Dynamic Stability in a Micro-Grid System”, *Conference on Emerging Devices and Smart*

Systems (ICEDSS), 2nd and 3rd March, organized by mahendra Engineering College, Mallasamudram, 2018; 38-41.

10. CS Lakshmi, C Nagarajan, "Neural Controlled Multi-Level Inverter Based DVR for Power Quality Improvement", *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 42-47.
11. S Thirunavukkarasu, C Nagarajan, "Performance Analysis of BLDC Motor Drive for Feed Drives", *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 67-70.
12. JP Daniel, C Nagarajan, "Hybrid Filter for Distorted Voltage Source in Microgrids", *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 11-15.
13. K Umadevi, C Nagarajan, "High Gain Ratio Boost-Fly Back DC-DC Converter using Capacitor Coupling", *Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March*, organized by mahendra Engineering College, Mallasamudram, 2018; 64-66.
14. C.Nagarajan and M.Madheswaran, "Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis", *Iranian Journal of Electrical and Electronic Engineering*, 2012; 8(3): 259-267.
15. Santhana Lakshmi and C. Nagarajan, "Multiconverter Technology Based Voltage Compensation for Photovoltaic System" *Ecology, Environment and Conservation*, 2017; 23: 226-229.
16. C.Nagarajan and M.Madheswaran, "Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques", *Electric Power Components and Systems*, 2011; 39(8): 780-793.
17. C.Nagarajan, M.Muruganandam and D.Ramasubramanian – 'Analysis and Design of CLL Resonant Converter for Solar Panel - Battery systems- *International Journal of Intelligent systems and Applications*, 2013; 5(1): 52-58.
18. C.Nagarajan and M.Madheswaran, "Experimental Study and Comparative Analysis of CLL-T and LCL-T Series Parallel Resonant Converter with Fuzzy/ PID Controller", *Journal of Electrical Engineering*, 2011; 11(3): 122-129.
19. C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has

been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai, 2007; 1: 190-195.

20. Nagarajan, M.Madheswaran and D.Ramasubramanian, "Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model," *Acta Electrotechnica et Informatica Journal*, 2013; 13(2): 18-31.
21. S.Sathish Kumar and C.Nagarajan, "Performance - Economic and Energy Loss analysis of 80 KWp Grid Connected Roof Top Transformer less Photovoltaic power Plant," *Circuits and Systems*, 2016; 7(6): 662-679.
22. Padmapriya S, Kumar R., "E-Tracking System For Municipal Solid Waste Management Using RFID Technology". *International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development*, 2014; 1(2).