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Design and Analysis of Unhurried Heat Process Using Various Control Strategies

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ABSTRACT: The objective of the work is to maintain the temperature in the closed loop at desired set value. The temperature tank has the features of nonlinearity, sluggishness by tuning conventional PID methods. This paper focus on implementation of internal mode control (IMC) to obtain an optimal PID control setting for temperature process. System identification of the process is done by Two-point method. Here delay is approximated with First Order plus Pade Approximation. At first, a Proportional Integral Derivative (PID) controller based on IMC-PID setting is designed and the results are compared with Ziegler Nichols (ZN) and Tyreus-Luyben (TL) controller settings. The robustness of the controllers is endorsed by imposing regulatory disturbances. The simulation results confirm that IMC-PID controller has improved dynamic performance on disturbance rejection.

KEYWORDS: Water Heater, PID controller, Internal Model Control, Ziegler-Nichols and Tyreus-Luyben, Integral Square Error (ISE) and Mean Square Error (MSE).

I. INTRODUCTION

The PID control is the most commonly application of control strategy nowadays, with its simple arrangement, good robustness and wide application range, it is gradually highlighted in the control theory. It has been observed that, however, the existing PID controllers may not perform well in the complex control processes, such as the higher-order system and time-delay system. Efforts have been put to fix this problem, and numerous effective PID controller design and tuning methods for complex processes have been stated [1]

PID tuning has certainly been the key to reasonable performance and robustness. PID controller setting is proposed for several process model. There are three commonly used method of PID tuning, they are Internal Model Control [2], Ziegler- Nichols setting [3] and Tyreus-Luyben setting [4], which still used in several industrial applications. Internal Model Control allow system designer to specify the anticipated system behaviour. The robustness and performance of the model can controlled by the single parameter (λ). IMC-PID setting is one of the greatest closed- loop method among experts and researchers since it is the easy way to understand. In the context of IMC, Parameter of consequent close-loop models are enhanced with respect to error performance criteria such a Integral Square Error (ISE) and Mean Square Error. The Internal Model Control (IMC) structure offers an appropriate structure for satisfying the ideas. IMC [5] theory has been used earlier and autonomously by a number of other scholars. Using the IMC setting design technique, controller difficulty depends entirely on two factors: the difficulty of the model and the performance necessities indicated by the designer. IMC denotes to a methodical technique for control design based on the Q-parameterization [6] idea that is the source for many current control methods. IMC offers an approach for designing Q-parameterized controllers, has real-world appeal. As a result, IMC has been a widespread design technique in the chemical industries, mainly as a malicious for tuning single loop PID controllers.

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II. EXPERIMENTAL SETUP

The physical experimental system comprises of Heater, Rotameter, PLC, control valve, temperature controller, water supply, Analog to digital converter, solid state relay, RTD.

TABLE I: COMPONENTS OF EXPERIMENTAL SETUP

TABLE II: Technical description of experimental setup

Part name	Description
RTD Temperature	50 ~ 500 °C
Temperature transmitter	Input 4-20mA, Output1-5V
Solid state relay	5V
Motor Pump	0.5 HP 220v
Water Heater	500W
Rotameter	6 – 60L
Communication	USB

System Identification – Two Point method:

Two-time instants of the reaction curve are estimated for two-point methods in order to calculate the characteristic values of a FOPDT system. In this study, the two-point method proposed by Sundaresan and Krishnaswamy (1978) is used. Step response found by two-points method should be thinking without dead time. Because of the system has no dead time.

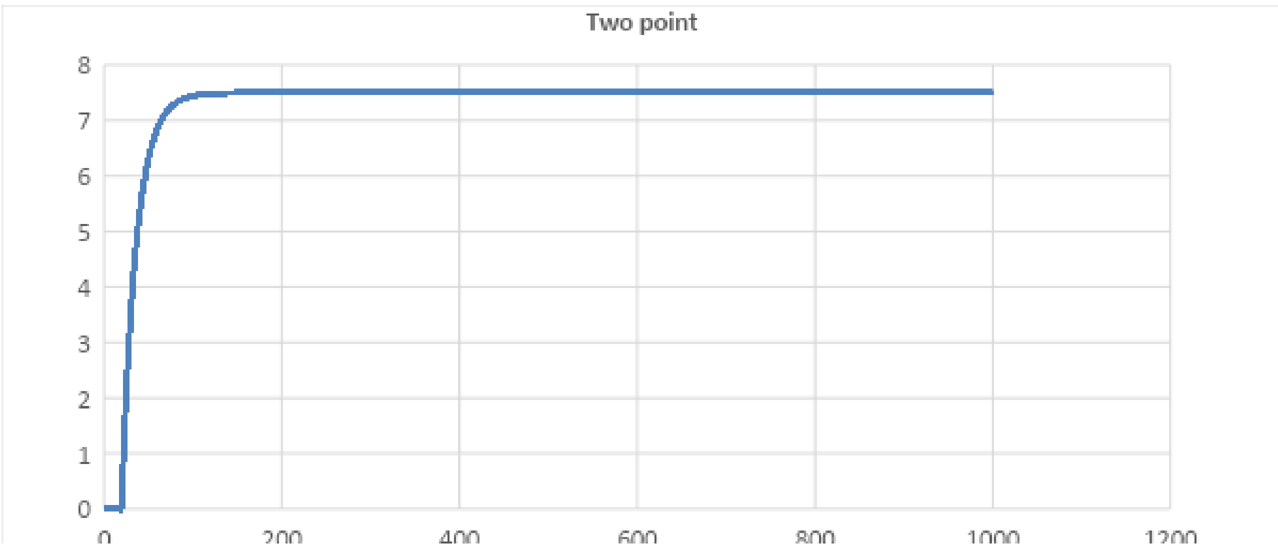

Figure: Close loop response of Two-point Method

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From this Graph we can find k_p, t and Ꞇ
The transfer function of Two-Point method given below.

$$G(s) = Ke^{-ts} / Ꞇs + 1$$

Where k_p is the steady state gain, t is dead time,

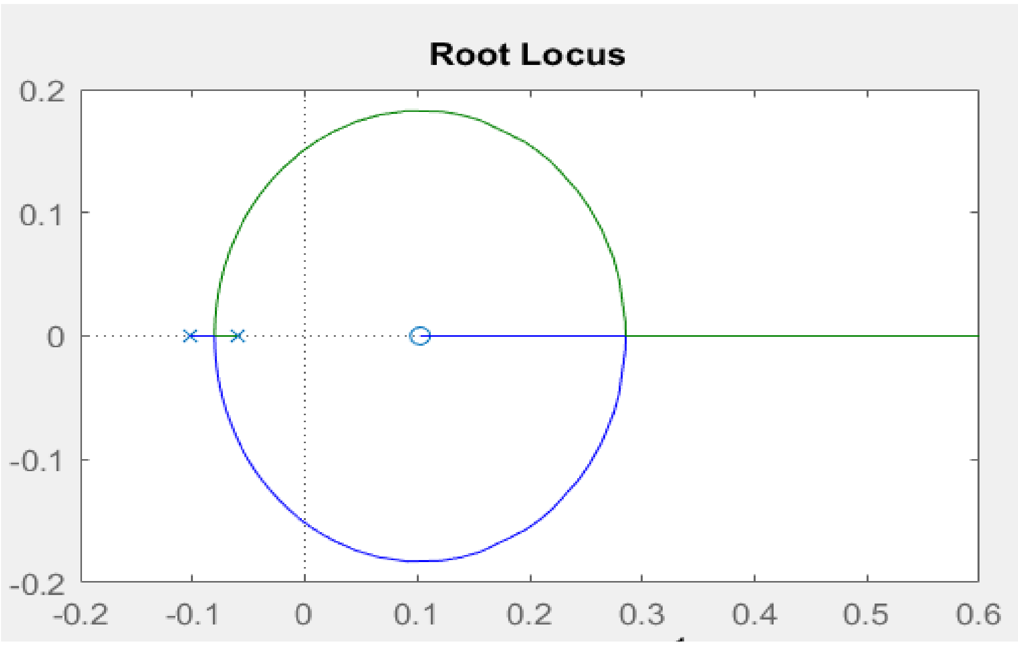
$$G(s) = 0.1875e^{-19.5s} / 16.5s + 1$$

III. CONTROLLER DESIGN

This paper reports the implementation of PID parameters in three design setting. The ZN-PID method, Tyreus-Luyben and IMC-PID method. With these techniques, tuning of PID parameters is accomplished to achieve a robust design with the anticipated response time. PID controller is tuned by physically regulating design criteria in three design modes. The response has approximately the similar set point after a comparatively extended settling period.

A. ZN and TL based PID:

The procedure to find Ziegler-Nicholas, Tyreus-Luyben PID controller we should know Ultimate Gain (K_u) and Ultimate Period (P_u). using MATLAB code, we can find ultimate gain and ultimate period.



From above diagram we can find **gain** and **Frequency (ω)** where $p_u = 2\pi / \omega$.

TABLE III: ZN-PID and TL-PID CONTROL PARAMETERS

PID	K_p	T_i	T_d
Ziegler-Nicholas	$0.6K_u$	$P_u / 2$	$P_u / 8$
Tyreus-Luyben	$K_u / 3.2$	$2.2P_u$	$P_u / 6.3$

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B. IMC based PID:

Internal model control (IMC-PID) is based on a precise model based on the mathematical model of the process. The control system leads to stable and robust. A stable **control** system is one which keeps suitable control action for the dynamic changes in the control system.

IMC controller settings,

$K_p = (Ꞇ + 0.5\theta) / K_p (\lambda + 0.5\theta)$

$T_i = Ꞇ + 0.5\theta$

$T_d = Ꞇ * \theta / 2Ꞇ + \theta$

Where $\lambda > 0.8\theta$, $K_i = K_P / T_i$, $K_d = K_p * T_d$

TABLE IV: CONTROLLER PARAMETERS

Parameter	K_p	K_i	K_d
IMC-PID	5.52268	0.21039	33.8467
ZN-PID	8.76	0.41834	45.8586
TL-PID	4.5625	0.049519	30.32694

IV. RESULT AND DISCUSSION

Internal Model Control, Ziegler Nichols and Tyreus-Luyben Closed Loop Response for PID Controller The transfer function obtained through empirical method of modelling is used as the system for studying the performance of PID Controllers by IMC, ZN, TL closed loop response for PID controller as shown in figure below for the temperature control system for water temperature system is shown in figure.

TABLE V: COMPARISION OF PERFORMANCE INDEX

Specification	IMC-PID	ZN-PID	TL-PID
MSE	1.35	1.94	1.35
ISE	0.042	0.048	0.047

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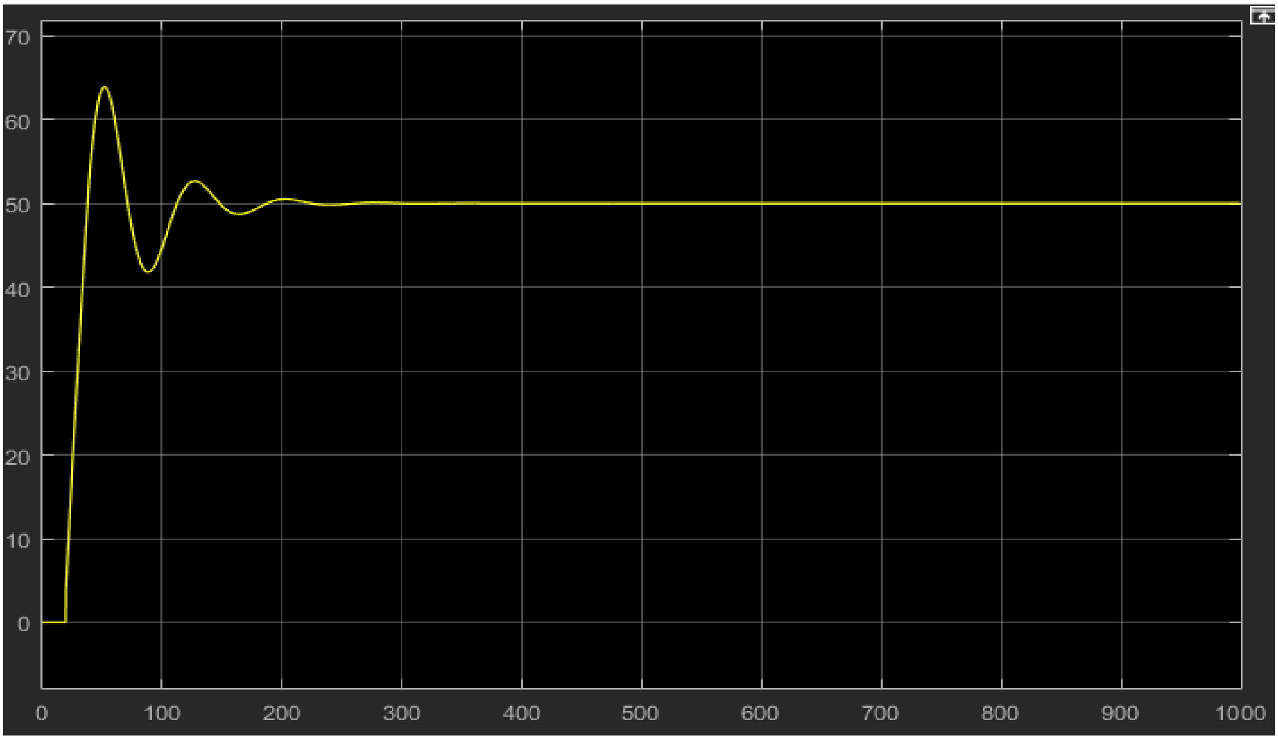

Figure: Close loop response for IMC

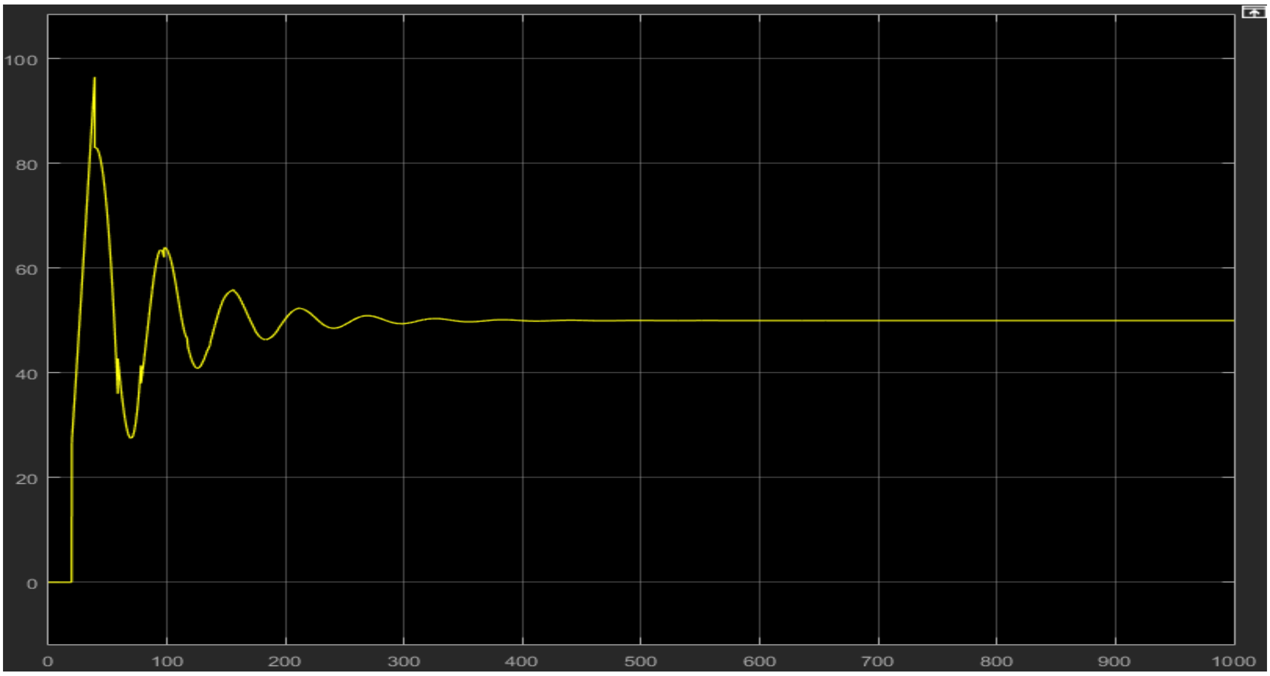

Figure: Close loop response for ZN

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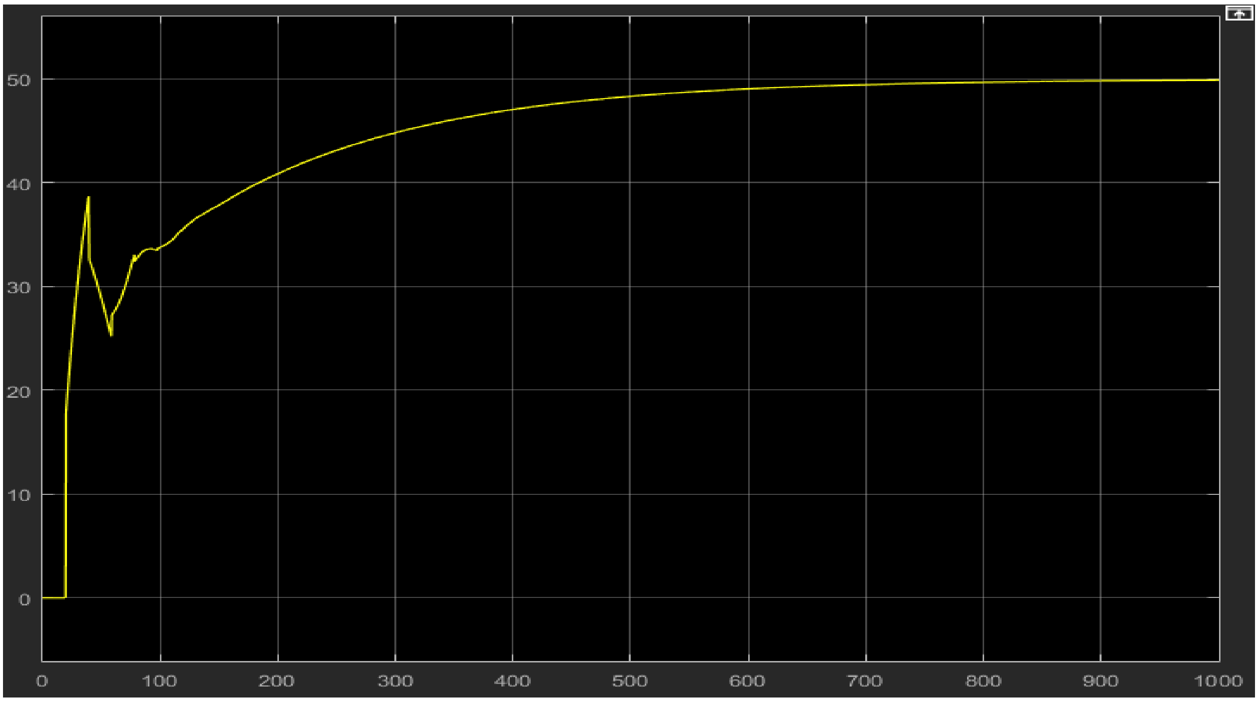

Figure: Close loop response for ZN

Load change response of a process for PID controller is shown is figure and given below and it evidently states how quick the IMC-PID, ZN-PID and TL-PID reacts to disturbance. Given below

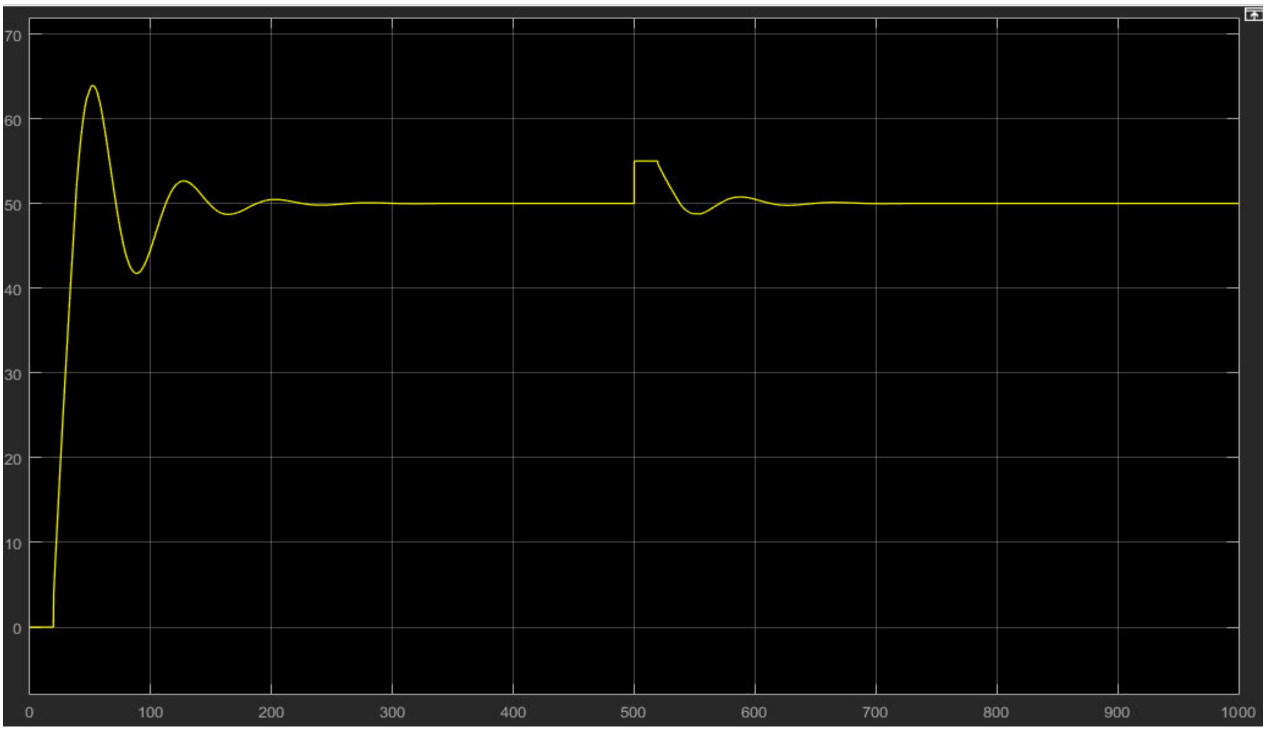

Figure: Regulatory response for IMC

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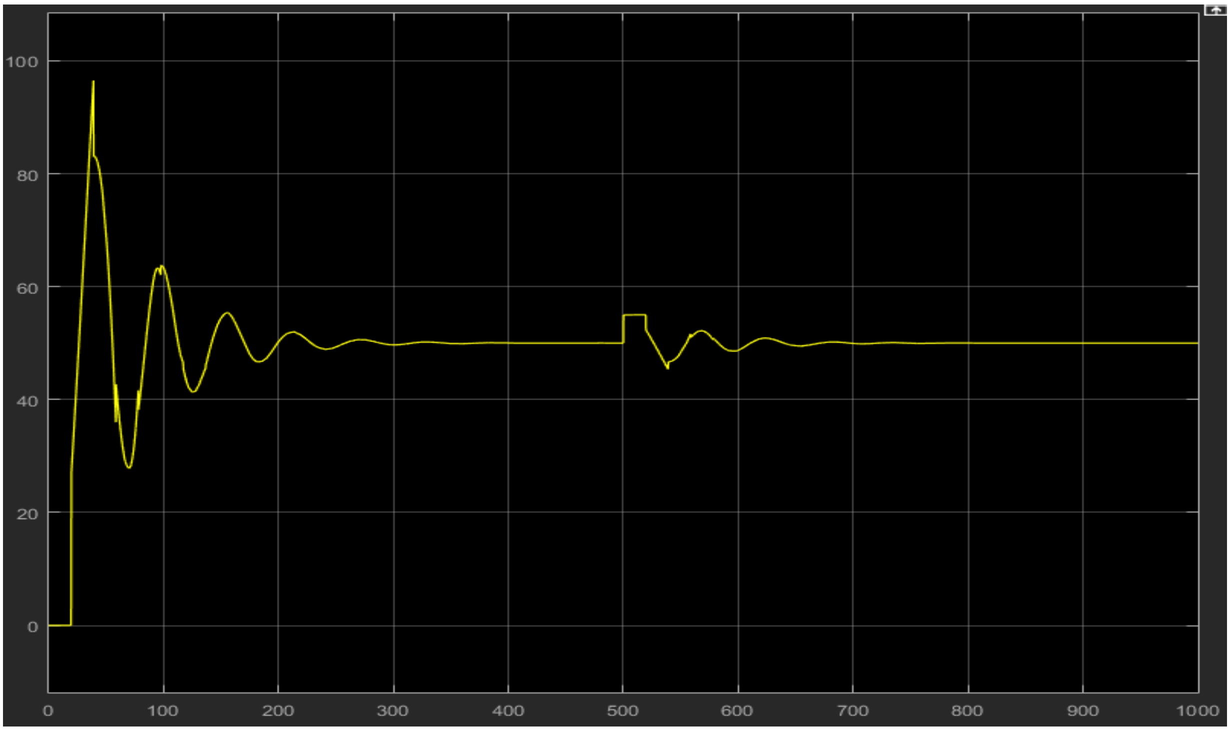

Figure: Regulatory response for ZN

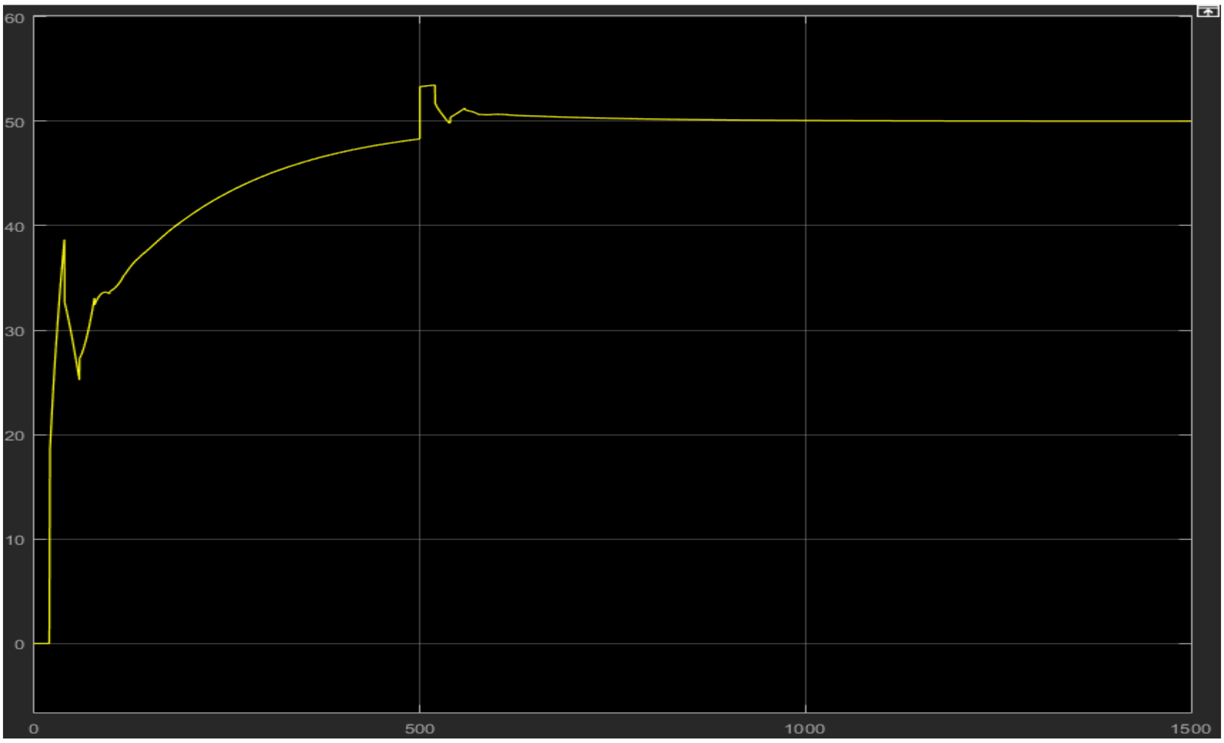

Figure: Regulatory response for ZN

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V. CONCLUSION

An IMC, Z-N and T-L are implemented to control the outlet temperature of water tank. The mathematical model has been presented in this study and compared with experimental results. Performance IMC tuning method is compared with Z-N and T-L by using (MSE) and (ISE). The results show that performance of the IMC tuning method is better than Z-N and T-L for the temperature control system.

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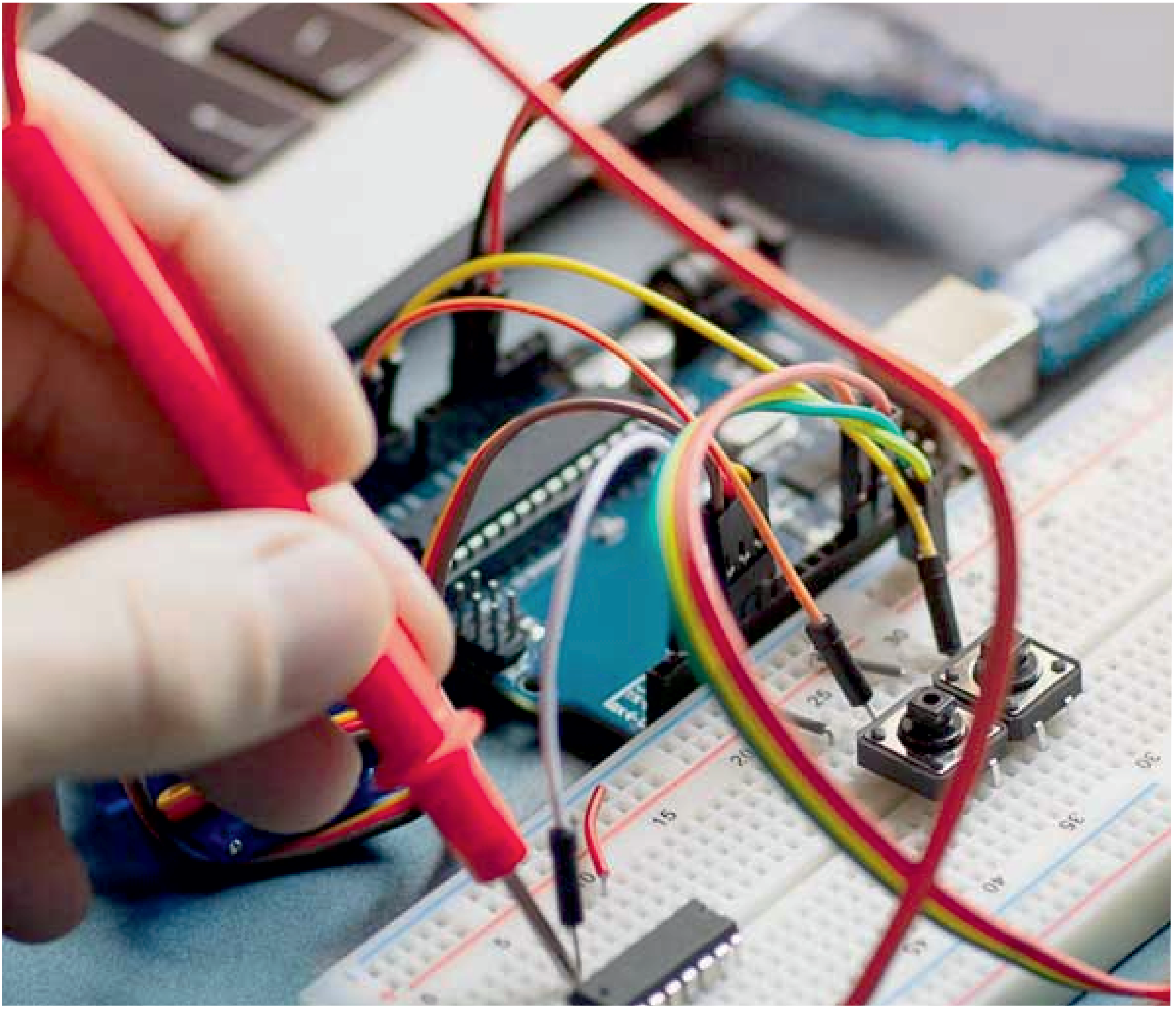

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