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Self-Tuning Regulator (STR) on Solar Energy-Based Herbs Drying System

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Abstract: This study emphasized on controller design for improving temperature regulation for solar based-energy herbs drying system. Therefore, the Self-Tuning Regulator (STR) controller is adapted on temperature regulation of solar based-energy herbs drying system. The transient analysis of the response found that Self-Tuning Regulator (STR) capable to prevent the response from the overshoot and provide 64.9% faster settling time as compared with PID controller.

Keywords: Self-Tuning Regulator (STR), PID, Temperature Regulation, Herbs Drying Process.

1. Introduction

An herbal spice is a plant or part of a plant used for medicinal, culinary and cosmetic purposes. Herbal medicine is still the general and widely used in the world population which mainly in the evolving countries for the primary health care [1]. However, fresh herbs are highly perishable since their posses high moisture content [2]. Therefore, in order to increase the shelf life of herbs, herbs need to be dried [3]. The sun-drying is the traditional method used for drying the herbs by hanging the herbs at outdoor [4]. However, sun drying method can lead end product degradation such as color and aroma of dried herbs [5]. Based on this factor, large number of studies related with herbs drying has been conducted including the study related with development new approach of herbs drying aimed to improved product quality and minimiz drying time. Solar energy based herbs drying system is one of the important approach that has been studied and developed recently to dry the herb [5]. However, there is lack of study related with temperature regulation of solar energy based herb drying system eventhough temperature plays significant role in herbs drying particularly in minimizing drying time and product quality. Therefore this study focus on implementation of controller namely Self-Tuning Regulator (STR) toward improving temperature regulator of solar energy-based herb drying system.

The remaining parts of this paper are organized as follows. Section two explains on the design of Self-Tuning Regulator (STR) for temperature regulation of solar energy-based herb drying system.

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Meanwhile PID controller with Cohen Coon tuning design used as benchmarks with STR is explained in section 3. The results and discussion are presented in section 4 and section 5.

2. Self-tuning regulator (STR)

In this study, the first order self-tuning regulator (STR) described in [6] is used. The control law for the controller can be described as Eq *1*

$$u = \frac{T}{R}r - \frac{S}{R}y = \frac{b_{mo}}{b_0}r - \frac{a_{m1} - a_1}{b_0}y \qquad Eq.1$$

In this work, the design of first order STR for temperature regulation of the system is based on solar energy-based herbs drying ARX model described in [7]. The ARX model for the system is as shown in Eq *2*

$$G(z) = \frac{B(z)}{A(z)} = \frac{0.7094}{Z - 0.9921} = \frac{b_o}{Z + a_1} \qquad Eq.2$$

Whereas, the reference model transfer function is designed with rise time, *Tr* equal to 53 seconds. The resulted transfer function for reference model is as shown in Eq *3*

$$H(s) = \frac{1}{24.09\,s + 1} \qquad Eq.3$$

By discretizing this model at a sample period, Ts = 1 second, the discretized model defined in Eq. *4* Hence, $a_{m1} = -0.9593$ and $b_{mo} = 0.04066$.

$$H(z) = \frac{0.04066}{Z - 0.9593} = \frac{b_{mo}}{q + a_{m1}} \qquad Eq.4$$

Subsequently, the control law had designed based on the parameters of plant model and reference model.

$$u = \frac{T}{R}r - \frac{S}{R}y \qquad Eq.5$$

$$u = \frac{b_{mo}}{b_0}r - \frac{a_{m1} - a_1}{b_0}y \qquad Eq.6$$

$$u = \frac{0.04066}{0.7094}r - \frac{-0.9593 - (-0.9921)}{0.7094}y \qquad Eq.7$$

Thus the resulted control law of first order STR for temperature regulation of solar energy-based herb drying system is shown in Eq. *8.*

$$u = 0.05732r - 0.04624y \qquad Eq.8$$

3. PID Controller

Proportional-Integral-Derivative (PID) controller is well known controller and has been applied widely in industry due to its capability in providing sufficient transient and steady state response in majority proceses. Based on this capability, PID controller is used as a benchmarks with STR controller in regulating temperature of solar energy-based herb drying system. In this work, The design of PID is based on Cohen Coon tuning formula as shown in Table 1. Meanwhile, the process parameter for calculating PID parameter is obtained based on Process Reaction Curve shown in Figure 1.

Table 1: Cohen-Coon tuning formula

PID Tuning	Proportional Gain, K_p	Integral Time Constant, T_i	Derivative Time Constant, T_d
Cohen-Coon	$\frac{\tau}{K\theta}(\frac{4}{3}+\frac{\theta}{4\tau})$	$\theta(\frac{32+6(\frac{\theta}{\tau})}{13+8(\frac{\theta}{\tau})})$	$\theta(\frac{4}{11+2(\frac{\theta}{\tau})})$

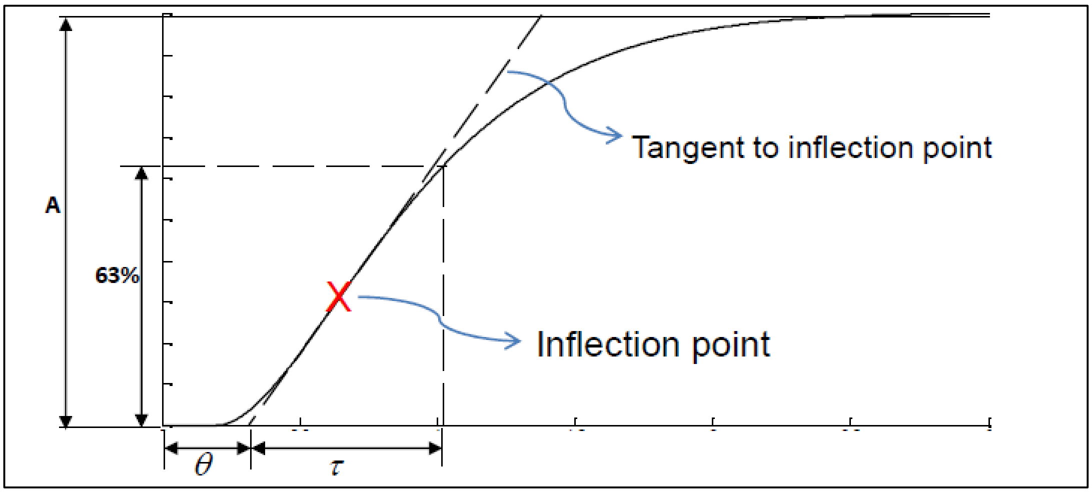

Figure 1: Tangent and point methods [8]

Based on open loop experimental data obtained in [7], the PID parameter for temperature regulation of solar energy-based herb drying system is as shown in Table 2.

Table 2: PID controller parameter

PID Tuning	Proportional Gain, K_p	Integral Gain, K_i	Derivative Gain, K_d
Cohen-Coon	0.255572	0.004310	2.2880

4. Results and Discussion

During the experiment, the temperature set point has been set at 40°C. This temperature range is selected since it within the temperature range applied by [9]. Figure 2 shows the comparative performance between STR and PID with Cohen Coon tuning controller in regulation of temperature for solar energy-based herb drying. The analysis of both response is tabulated in Table 3.

The analysis shows that STR controller achieved settling time at 119.93 second and this is 64.9% faster as compared with time required by PID controller to achieved it settling time. Apart from that, the analysis also clearly shows that STR controller capable to prevent the response from overshoot, while PID controller produced 37.14% overshoot. Based on this results, it reveal that STR capable to provide better performance as compared with PID controller in regulating temperature of solar energy-based herb drying system.

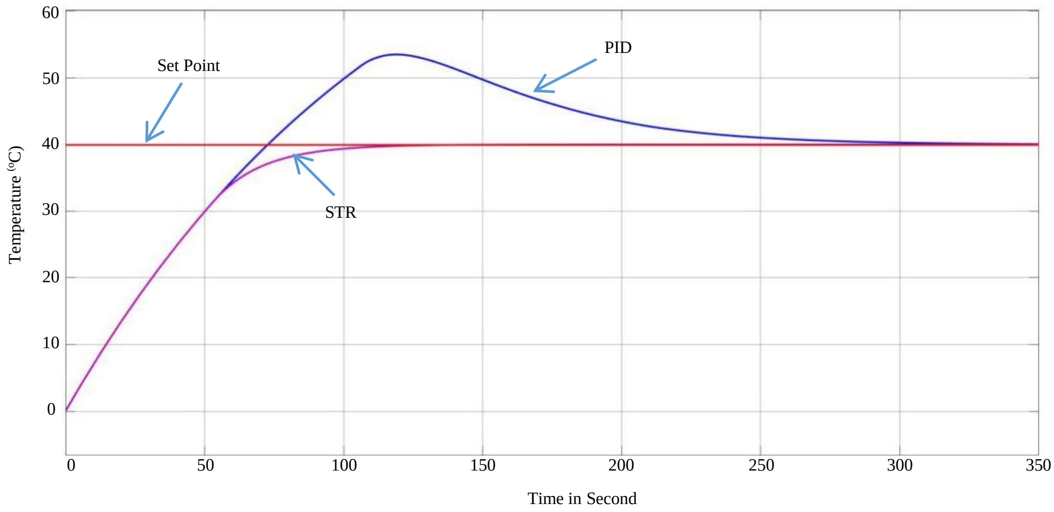

Figure 2: Comparison response of the PID controller with cohen-coon tuning and STR controller

Table 3: Analysis transient response of the PID controller with cohen-coon tuning and STR controller

Controller	Settling Time (s)	Percentage Maximum Overshoot (%)
PID Controller with Cohen-Coon	342.65s	37.14%
STR	119.93s	0%

5. Conclusion

The main objective of this study is to evaluate the performance of Self-Tuning Regulator (STR) controller on temperature regulation of solar energy-based herbs drying system. From the comparative analysis, it concluded that Self-Tuning Regulator (STR) controller capable to provide better performance particularly in providing faster settling time and preventing response overshoot as compared with PID controller in regulating temperature of solar energy-based herbs drying system. This shows that STR is one of the candidate controller that capable in improving temperature regulation of solar energy-based herbs drying system towards increased the efficiency of solar energy-based herb drying process.

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