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Glycerin Purification Process Plant System Design and Performance

ZuriatiJanin, Hazilah Mad Kaidi, Robiah Ahmad

Abstract: Pure glycerin is normally adopted for the production of cosmetics, personal care and food industryin order to produce quality end-products. Most crude glycerin, however, contains a sticky substance and coloring materials that may affect the flavor and color of the end-product. This paper presents the design and development of the glycerin purification process plant system to purify the crude glycerin through heating process. The process system is designed and developed based on the information gathered from literature. The system architecture of the process plant is developed using industrial instrumentations and hardware system found in the laboratory. The choice of transducer and final control element used is based on the needs of the developed system. Glycerin purification is a process of removing the peroxides and the secondary products found in the crude in which the process is significantly depends on the operating temperature. In this work, the temperature control system for glycerin heating process is designed and the process controllability in terms of settling time and percent overshoot is experimented using PID controller. The results of the experiments show that the developed glycerin purification process plant system is workable and able to provide good temperature control system performance for glycerin heating process. PID controller with correct controller parameters adjustment can improve the glycerin heating process system performance. The main contribution of this paper is the development of the glycerin purification process plant system in which the system implemented is different from any of the related publications in the aspects of instrumentation and hardware system used.

Keywords* : *Glycerin, purification, process plant, PID

I. INTRODUCTION

Thereis an abundance of percentage usage of glycerin in the food industry and production of cosmetics and personal care[1, 2]. Glycerin is an odorless and colorless liquid that forms a pasted at the freezing point[3, 4]. Crude glycerin can be obtained from the bio-product of soybeans, sunflower, palm, corn, coconut and so on[5-8]. However, the crude glycerin obtained from the refining process stage is highly containing color pigments and other impurities that may affect the color, flavor and odor of the end-product[3, 9-10].

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Thus, the glycerin purification process plant is developed with the aim to produce purified colorless glycerin. In this work, the development of the process plant is based on the industrial actuators and instrumentation.

The purification of crude glycerin is an important process whereby significantly depending on the operating temperature[5,11-17]. For instance, when the heating process experiencing any temperature changes, the changes should dissipate quickly to avoid more formation of hydro-peroxides and secondary oxidation products in the final purified glycerin[13, 18-21]. Hence, it is also aimed to study the temperature control system controllability of the developed glycerin purification process plant.

II. GLYCERIN PURIFICATION PROCESS PLANT SYSTEM DESIGN

A. System Architecture

In this work, the design and development of glycerin purification process plant system is based on the information gathered from[3, 9-12,16, 22-26]. In general, the capability and availability of the system hardware play vital role so that the process plant can work effectively and efficiently. Pertaining to this, the main hardware system for the glycerin purification process plant development are including the primary measuring devices and final control elements.

The overall system architecture for glycerin purification process plant is as shown in Fig. 1. As shown, there are three functional levels in which the first level consists of the process plant hardware system. The second level is the data acquisition system hardware and software. The second level is to establish communication between the first layer and the third layer. The third level consist of software interface.

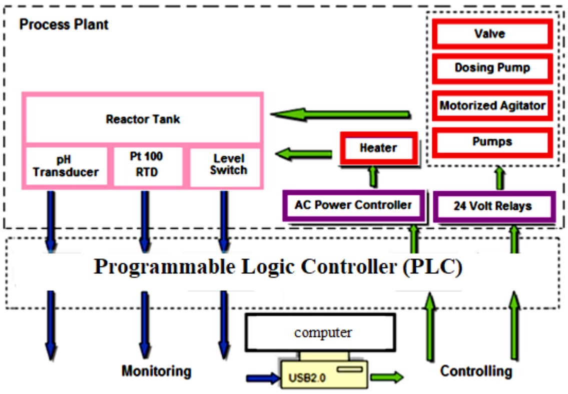

Fig. 1.Overall system architecture for glycerin purification process plant

B. Transducer and Final Control Element

The primary measuring devices are including the RTD Pt100 and level switches that provide information about the relevant process measurement. Meanwhile the final control elements are including the ac power controller and heater, control valve, pumps and motorized stirrer that provide some status input information in response to a change in control system input. The selection of the transducers, final control element and other main instrumentation is basically according to the device characteristics, principles of operation and measurement capabilities in conformance to specifications[27]. In this work, the RTD Pt100 is calibrated to maintain optimum operating condition particularly at process interface.

The three wire RTD Pt100 connection is as shown in Fig. 3. When the switch is at position 1, the voltage across the RTD is measured using (1)

$$V_{RTD} = I_S * (R_{RTD} + R_{W1} + R_{W3}) \quad (1)$$

The voltage across the wire resistance is then can be calculated using (2)

$$V_{wire} = I_S * (R_{w2} + R_{W3}) (2)$$

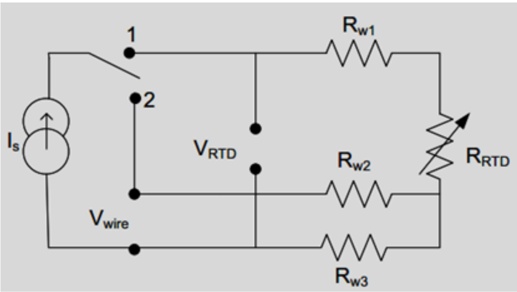

Fig. 2.Three wire RTD Pt100 connection

The RTD is calibrated in such that the current signal of 4 to 20 mA that sent through a 250 Ω resistor causing a voltage output signal of 1 to 5 Volt. This voltage signal range corresponds to the temperature range of 0 °C to 100 °C with a linear relation between the ranges.

The ac power controller shown in Fig. 3 is used to control the power that transmitted to the heater. In this work, the powerof 0% to 100% range that sent to the heater varies in proportion to the input current signal of 4 to 20 mA range.

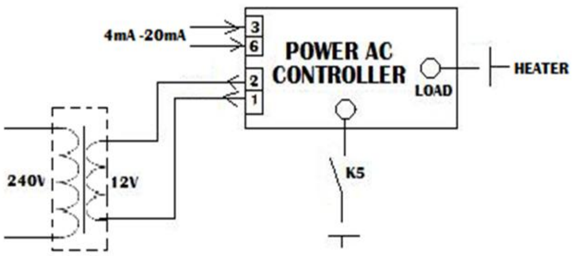

Fig. 3.AC power controller wiring diagram

The voltage that delivered to the heater for a fraction of the cycle is determined by applying the triac gating signal[27].

C. Programmable Logic Controller (PLC)

The operation of the developed glycerin purification process plant was established using on the shelf available OMRON CPM1A programmable logic controller (PLC) and based on the temperature control system flow design shown in Fig. 4.

The PLC is used for starting up and shutting down the whole process sequence and for the management of alarms and emergency shutdown. The PLC is operated by continually scanning a program in which the PLC is responsible to send high or low signal to all the process plant hardware system. The process plant is programmed in such that the user can either control the final control element directly without to follow the process sequences or to execute the whole process plant sequences. In this work, the main hardware system is connected via relays for activation in which the relay is normally-closed when the digital output terminal associated with the channel applies a 24V voltage signal. Otherwise, the relay is normally-open when the voltage signal is not applied to the output terminal.

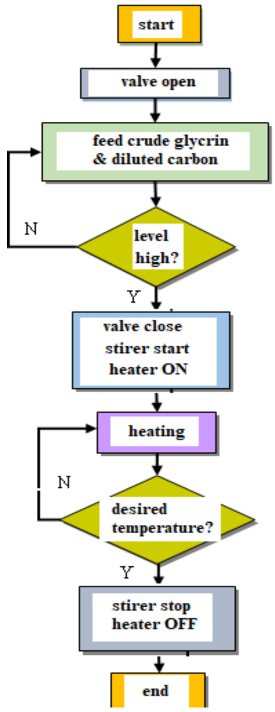

Fig. 4.Temperature control system flow design

III. TEMPERATURE CONTROL SYSTEM DESIGN

The temperature control system for glycerin heating process is designed in such that the improvement of purificationprocess is determined by controlling the power fed to the heater. This is as illustrated in Fig. 5.

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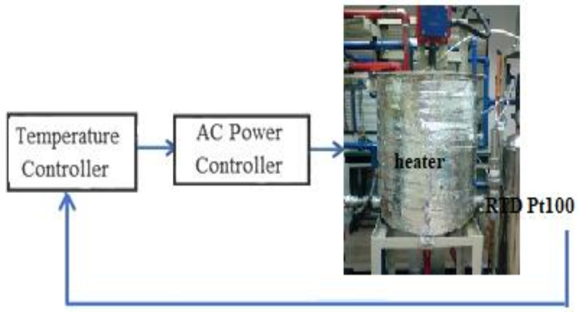


Fig. 5.Block diagram for glycerin temperature control

In this work, it is desired to maintain the temperature at 85°C in which the heater only comes into action when the measured temperature is differs from the desired value. The power fed to the heater is carried out using phase angle power control method in which the ac power controller is turned ON at a certain phase angle that varies in proportion to the input current signal of 4 to 20 mA range.

A. PID Controller

The PID controller described in (3) with filtering constant, α ϵ [0, 1] was implemented to the system in which the controller was designed using Ziegler-Nichols method[28-30]. The process system performance is then observed and evaluated.

$$G_{PID}(s) = K_p\left(1 + \frac{1}{T_i s} + \frac{T_d s}{\alpha T_d s + 1}\right) \quad (3)$$

whereKp is the proportional gain, Ti is the integral time and Td is the derivative time.

The controller parameters can be adjusted using Ziegler-Nichols method as shown in (4) – (6).

$$K_p = \frac{1.2kT}{L} \quad (4)$$

$$Ti = 2L \quad (5)$$

$$Td = 0.5L \quad (6)$$

The process response performance in terms of rise time, settling time and percent overshoot is observed and discussed.

IV. PROCESS MODEL ESTIMATION

The process model for glycerin heating process is estimated as first order plus dead time (FOPDT) model as shown in (7).

$$G(s) = \frac{Ke^{-Ls}}{Ts+1} \quad (7)$$

where K is the process gain, L> 0 is the delay time and T> 0 is the process time constant. The model in (7) is selected because it allows simple experimental identification from the step response, which can be easily measured[31]. The transfer function parameters of the process are obtained by doing the step input test to the developed process plant.

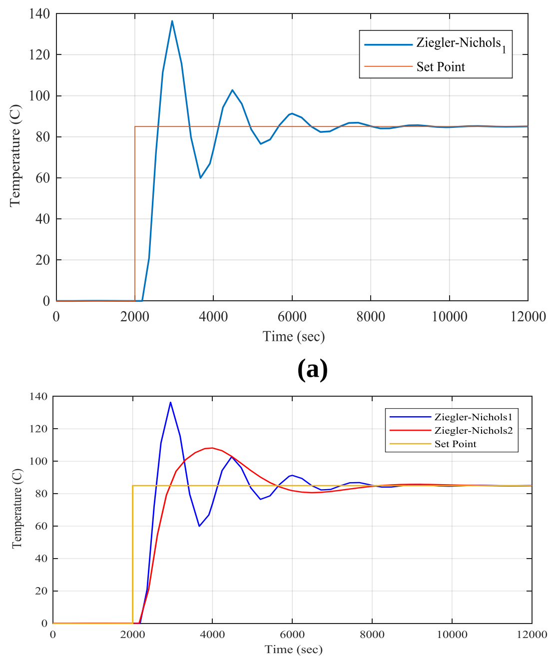
A 15% step input current signal change is applied to the process plant system and the output response is observed until the process reaches the steady state.Using two-point method, the process model is experimentally obtained as 4.8/(3397s+1) *e^{-420s}.

V. RESULT AND DISCUSSION

Fig. 6.Glycerin purification process plant system

Fig. 6 shows the developed glycerin purification process plant system. The system implemented is different from any of the related publications in the aspect of instrumentation and hardware used.

Based on the process model obtained from the input step experiment, the controller parameters are designed using Ziegler-Nichols. The resulting transient response criteria are as shown in Table I. The corresponding closed-loop step responses are as shown in Fig. 7.



(b)

Fig. 7.PID closed-loop process response (a) Ziegler-Nichols (b) Performance comparison

As shown in Fig. 7a, the rise time was quite fast, but the response exhibits a significant overshoot, some undershoots and took longer time to settle. The resulting closed-loop response for PID Ziegler-Nichols for new adjusted controller parameters is shown in Fig. 7b. As shown, the rise time and the settling time are slightly increase, but the overshoot was decrease to 27.5% as compared to the previous performance.

The result had shown that the process performance is much dependson the amount of controller parameters adjustment and method used. The best suited control scheme to control the glycerin heating process can be further research in which the improvement in glycerin temperature control contributes to the best achievement of the desired quality of the purified glycerin.

Table- I: Closed-Loop Process Response Performance

Method	Controller Parameters Adjustment			Response Performance		
	Kp	Ti	Td	Rise Time	Settling Time	Percent Overshoot
Ziegler-Nichols	2	840	210	298.5	7701.2	60.4
	0.5	840	210	561.8	7521.1	27.5

VI. CONCLUSION

The glycerin purification process plant system has successfully designed and developed.The temperature control system for glycerin heating process has also successfully designed and implemented. The developed glycerin purification process plant system is workable and able to provide good temperature control system performance for glycerin heating process.The glycerin temperature control system can be further researchfor best improvement and achievement of the desired purified glycerin.

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