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A Greenhouse Control System Based on Best-Fitted PID Controller to Minimize Energy Cost

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ABSTRACT

In these days, many of greenhouse environments are based on electric devices and ICT technologies. The model suggested in the paper the detailed design of a greenhouse control system adaptability with PID (Proportional Integral and Derivative) controller. Compared with a previous greenhouse control system (GCS), the proposed system is focused on the detailed design of greenhouse control process to minimize energy costs for crop growth in a greenhouse. In the suggested system, there are two important processes namely, Greenhouse Control Process (GCP) and Crop Growth Process (CGP). The two process data, which are crop status information and climate set-point information, are stored in an information storage database. The PID controller works inside the GCP and the environment control decision works inside the CGP. According to the service decision algorithm of it, the controller will work properly in a greenhouse. Using the suggested system with the different combinations such as P, PI, PD and PID, a user can easily simulate energy costs for a greenhouse system and efficiently design the best optimized controller in the greenhouse system. Therefore, the suggested system can provide a feasible solution to reduce or minimize energy cost in the greenhouse and help developments of various applications related with greenhouse environments.

KEYWORDS: Greenhouse control process, Crop growth process, PID controller, Climate setpoint, Energy cost

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1. Introduction

For past decade, agriculture has been improving ubiquitously. Nowadays, agriculture has applied artificial and automatically developed. The technology of development provides overwhelm to all village farmers. But, the automated agriculture absorbs more energy cost. Such that, due to ascent raw materials, oil prices and operating cost gradually increases [1]. So, the village farmers work very hard to increase profit. If the same situation continuous then the farmers won't be able to see profit [1]. Therefore, to increase the profit is important as well as possible to minimize energy cost is crucial in the agriculture sector. So, we want to minimize the energy cost in agriculture sector [2].

The main intent of this research is to control the energy cost or to minimize the energy cost [3,4]. In order to do this, we need PID controller and will be able to adapt the controller in greenhouse system [5]. The PID controller controls the input devices as much as possible to find the best solution in this system. An example of a greenhouse system, the two devices such as the heater and external heating fan [6]. These devices are absorbing more energy in the greenhouse system. To implement the PID controller in the greenhouse and then we get feasible solution [5]. In this study, we mainly focus on the heater and external heating fan in the greenhouse system. Thus, the PID controller is much possible to support in greenhouse system and also to control environmental inputs.

2. Greenhouse Control System

F. Lafont and J. F. Balmat, were published an Optimized fuzzy control of a greenhouse [7]. Zhang Qian and et al, examined a wireless solution for greenhouse monitoring and control system based on Zigbee technology [8]. Rodrigo Castaneda-Miranda and et al, analysed fuzzy greenhouse climate control system based on a field programmable gate array [9]. J. P. Coelho and et al, examined the greenhouse air temperature predictive control using the particles warm optimisation algorithm [10]. N. Bennis and et al, had been published the greenhouse climate modelling and robust control [11]. so, based on the related study, we analysed an optimization of greenhouse control system to minimize energy cost using PID controller.

2.1. Basic Information of PID Controller

The PID Controller stands for Proportional Integral and Derivative Controller, is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulated control [13]. A PID controller continuously calculates an error value as the difference between a desired setpoint and a measured process variable and applies a correction based on proportional, integral, and derivative terms [13]. Proportional term describes present value of error, Integral term describes past value of error, and the derivative term describes the future value of the error, based on the past and present value changes.

PID Controller Theory: The summed of the terms which constitute manipulated variable(MV). The mathematical equation of PID Controller is given below,

$$\mu_t = E_p e(t) + E_i \int_0^t e(\tau) d\tau + E_d \frac{de(t)}{dt} \quad \ldots$$

ref[8]

Where, μ_t = MV - output of PID Controller, MV(Manipulated Variable). $E_p, E_i, E_d,$ - Proportional gain, Integral gain and derivative gain constant respectively. $e(t) = (SP - PV)$ - error (SP is Set Point and PV is Process Variable). t - time and τ is variable of integration (τ values from 0 to t).

2.2. Design of Greenhouse Control System

There are two main processes in greenhouse control system, they are GCP and CGP. The GCP consists of information analyzer, greenhouse control model, and PID controller. The information analyzer is based on greenhouse control model and fetches the data from storage after delivered data collection and climate set points. The information analyzer provides environment factors to be controlled in PID controller by mentioned the analyzed data and climate set-points which are supplied from environmental set points decision. The value of PID controller is dispatched to the greenhouse, and it will control the greenhouse inside environment. The PID controller is used to control the controlling inputs (i.e. temperature) in the greenhouse and the greenhouse control model is select proper control input devices to greenhouse based on climate set points and information analyzer. After selecting the control inputs, to control the inside environment in the greenhouse with crops and then the information's are stored in the database.

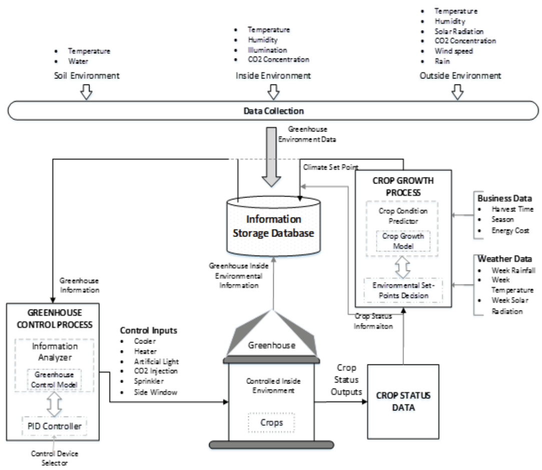

그림1. PID 컨트롤로 기반 온실 제어 시스템 다이어 그램

Figure 1. Diagram for Greenhouse Control System adapted with PID Controller

The another main process is CGP and it's consist of crop condition predictor, crop growth model, and environmental set-points decision. The crop status data provides crop status information to crop growth process. Using the crop status information, crop condition predictor is to predict the future value of crop condition, based on crop growth model by considering the weather data and business data on the growth status of the crop. The environmental set points decision plays an important deciding role in adjusting the greenhouse climate set-points based on extracted predicted data from the crop condition prediction.

The climate set-points are stored in information storage database and also move to greenhouse control process and then the same processes are aforementioned. <Figure 1> Shows that greenhouse control system adapted with PID controller.

2.3. Step-by-Step Process of Greenhouse Control Model

An algorithm is also known as a step-by-step process. In this study, one of the important roles is to control the device and/or to select the proper device in greenhouse control system. The device selection is based on inside greenhouse temperature. So, this study focused on temperature and depends on temperature, the other devices are work.

In this study, the user was fixed the set-point value i.e. temperature value. The temperature value is assigned to a constant temperature. If the inside greenhouse temperature is equal to a constant temperature, then the process will stop, else the process will move to next condition. If the inside temperature is greater than constant temperature, then checking the device status of the heater. If the heater is On, then it is turned Off. After turn Off the heater, the temperature value won't reduce in the greenhouse then the cooler or ventilation window is work based on temperature level.

If greenhouse inside temperature is less than constant temperature, then checking the device status of the cooler. If the cooler is On, then it will turn Off. Else, to activate any one of the both device i.e. heater or external heating fan. In

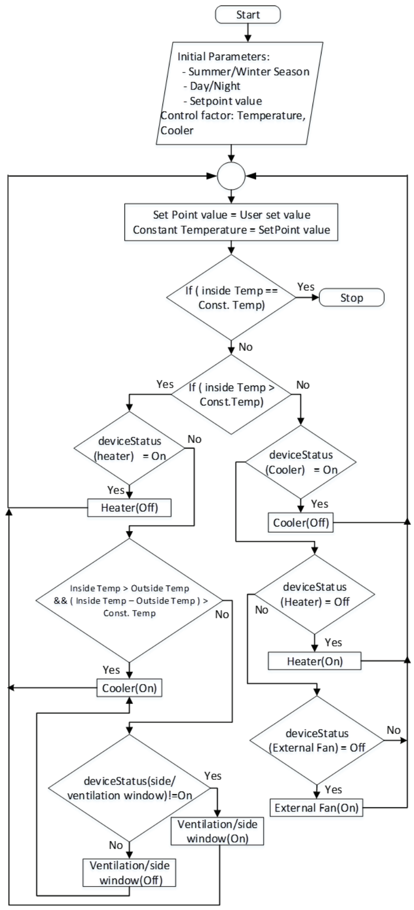

그림2. 온실 제어 모델 알고리즘

Figure 2. Algorithm of Greenhouse Control Model

greenhouse has required more temperature than to activate the heater. The heater produces more temperature and quickly heating system in the greenhouse. The external heating fan is producing to improve temperature step-by-step level. The greenhouse control device selection process continuously be working until the condition is satisfied. The user is fixed the set-point value based on the crop growth process within environment set-point decision. If greenhouse temperature is maintaining a constant temperature, then the loop will go to stop the process. Perhaps the temperature may be fluctuation in stop process, then the loop will go to start the process and then maintaining a constant temperature in the greenhouse. This work is repeated again and again whenever the temperature is required. <Figure 2> shows the step-by-step process of greenhouse control model.

3. Simulation of Green House Control Model

The simulation of P, PI, PD and PID controller are shown in <Figure 3>. Before simulation, the constant values of proportional gain (E_p), integral gain (E_i) and derivative gain (E_d) are required. In this simulation, E_p, E_i, and E_d values are maintained constant with respect to P, PI, PD and PID controllers. If the absence of any controller that particular gain values set to zero. (Ex: The absence of integral and derivative term is set to zero in P controller). There are different colors in the simulation they are green, violet and red colors which corresponding represent values are set-point, process variable and manipulated variable. The set-point value is user fixed the temperature value i.e. constant temperature in greenhouse. After setting that value, it could be processed that particular controller. The process variable is processing the set-point value and the manipulated variable is summed the overall (P or PI or PD or PID) term or output of the particular controller.

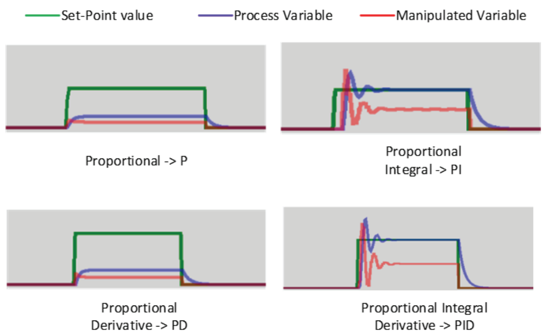

그림3. P,PI,PD 및 PID 시뮬레이션을 위한 다이어그램

Figure. 3 Diagram for P, PI, PD and PID Simulations

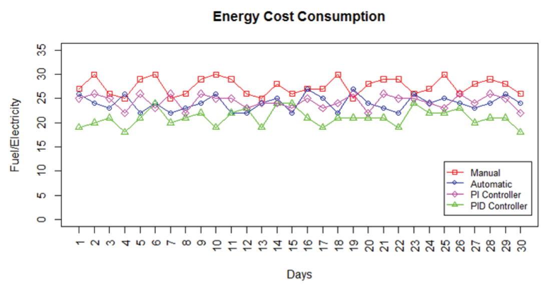

그림4. 에너지 소비 결과 비교

Figure. 4 Result of Energy Cost Consumption

There is a different kind of PID simulations took place and compared one to other then find best one of controllers in a greenhouse [15]. They are P, PI, PD and PID Simulations, where P and PD of process variable didn’t reach the set-point value. So, the P and PD controllers are not satisfied because of didn’t reach the target. In PI controller, the process variable reached the set-point value but the manipulated variable didn’t maintain stabilize. The PI controller is satisfied but it is not best controller in this simulations. In PID controller, the process variable reached the set-point value and the manipulated variable constantly maintained without variance. So, the PID controller is satisfied and gives the best output compared to other controllers in this simulation.

4. Result

The <Figure 4> shows that simple simulation of energy cost consumption and it's used very small amount of data. The data are generated randomly and contains 1-month data or 30 days' data of fuel/electricity energy. In this result, comparing four operators namely, manual, automatic, PI controller and PID controller. The manual operator refers operating the controllers manually, automatic operator refers operating the controllers automatically, PI controller refers Proportional and Integral terms of operating the controllers, and PID controller refers Proportional, Integral & Derivative terms of operating the controllers in the greenhouse. Based on this result the manual operator energy cost is high level, the automatic operator energy cost is in-between the range of manual and PI controller, PI operator energy cost is in-between the range of automatic and PID controller, and PID control operator energy cost is low level compared to remaining operators. In this result, the P and PD operators are not included, because in simulation part, both are not reached the (target value) set-point value. If they included then it's useless. so, we neglected the P and PD operators in the result. The four operators are manual, automatic, PI and PID controller and the corresponding reduced energy cost consumption approximately 5-10%, 10-20%, 12-22% and 15-30% respectively. So, the PID controller is highly control/reduce the energy cost approximately 15-30% in greenhouse control system. Thus, the PID controller is good and may possible to control or reduce energy cost in the greenhouse system.

5. Conclusion

In this study, the greenhouse control system has been designed for minimized energy cost and optimized control of greenhouse environment by communicating greenhouse control process and crop growth process. By implemented the PID controller in greenhouse system, as much as possible to control the inside environment of greenhouse and also to control and/or minimize energy cost. After we have to study about GCP to make set-point and CGP. In future works, we will create a new system adapt with new sophisticated technology based on analyzed of requirements in agriculture.

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에너지 비용 최소화를 위한 최적 PID 제어기 기반 온실 제어 시스템

바산트 라구, 이명배, 조용윤, 박장우, 신창선
순천대학교 정보통신공학과

요 약

최근의 대부분의 온실환경은 다양한 전기 기기와 ICT기술들을 포함하고 있다. 본 논문에서는 이전의 온실 제어 시스템과 비교했을 때, 온실에서 작물의 성장 과정에서의 에너지 비용을 최소화 하기 위한 온실 제어 프로세스의 세부 설계에 중점을 둔 PID 제어기를 이용한 온실 제어 시스템에 대하여 설계하였다. 제안된 시스템에는 GCP (Greenhouse Control Process)와 CGP (Crop Growth Process)의 두 가지 중요한 프로세스가 있으며, 작물 상태 정보와 기후 설정 값 정보 인 두 프로세스 데이터는 정보 저장 데이터베이스에 저장된다. PID 컨트롤러는 GCP 내부에서 작동하며 환경 제어는 CGP 내부에서 결정된다. 사용자는 P, PI, PD 및 PID와 같은 다양한 조합으로 제안 된 시스템을 사용하여 온실 시스템의 에너지 비용을 쉽게 시뮬레이션하고 온실 시스템에서 최적화 된 컨트롤러를 효율적으로 설계 할 수 있다. 제안 시스템을 기반으로 온실의 에너지 비용을 줄이고 온실 환경과 관련된 다양한 응용 개발에 활용에 할 수 있는 솔루션을 제공 할 수 있다.

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