UNIVERSITI TEKNOLOGI MARA

HYBRID FUZZY-PID CONTROLLER INTEGRATED WITH ANTI WIND-UP STRATEGY FOR SMALL-MEDIUM INDUSTRY SCALE STEAM DISTILLATION PLANT

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Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Electrical Engineering)

Faculty of Electrical Engineering

September 2025

ABSTRACT

The current demand for essential oil is in explosive growth due to the interest of usage in major end-use industries such as; food and beverage, pharmaceuticals, cosmetics, and aromatherapy. Essential oils can be extracted via various extraction methods ranging from classical to modern techniques. However, the most common and famous technique approach in essential oil extraction technology is the steam distillation technique. There are common influencing parameters affecting the quality of the essential oils in all extraction process of essential oils with temperature being the most influential parameter. Hence, the study solely focusses on controlling the temperature. Regulating temperature is simple, but the process is much more complicated because many low molecular weight volatile compounds break down when exposed to high temperatures due to their instability. Unfortunately, in most studies, essential oils are extracted under minimal or without supervision when it comes to temperature control. The control strategy integration is crucial and necessary as an elevation of several degrees in temperature can affect the chemical structure composition of essential oils. However, the effort to regulate the system at the desired set-point is very challenging due to non-linearities in dynamic behaviour. Most practitioners and engineers still rely on conventional PID control method to control applications. Conventional PID controller is the famous controller in many applications due to its simple structure which is easy to develop. Unfortunately, numerous researchers claimed that PID has some weaknesses for certain applications. The main drawback of conventional PID comes from the control variable; which is delay in corrective action to drive to the desired set-point. This is inadequate and not capable of regulating a non-linear system. In addition, the integral action is unable to improve the system once the control signal exceeding the physical operating range of the actuator. Consequently, the wind-up phenomenon occurs due to actuator limitation and non-linearities of the system. The phenomenon contributes to high overshoot and long settling time. Hence, the implementation of an advanced controller such as the Fuzzy controller will enhance the set point tracking performance. Several type controllers such as PID controller, PID Anti-Wind-up (PIDAW) controller, Hybrid Fuzzy-PID (HFPID) controller, and Hybrid Fuzzy-PID Controller with Integrated Anti-Wind-Up Strategy (HFPIDAW) were proposed to control steam temperature in Small-Medium Industry Steam Distillation Plants (SMISDs). These controller performances were evaluated based on their steady state response and transient response. The qualitative analysis were performed by applying rise time, settling time, percentage of overshoot, RMSE, ISE, IAE, and ITAE in simulation and real-time studies. The evaluation on the performance of these controllers were evaluated and the finding reveals that; HFPIDAW controller achieved better performance in terms of transient response and steady state response compared to other PID, PIDAW and HFPID based controllers. The HFPIDAW controller tuned by smallest of Tracking Time Constant, T_d value successfully managed to contribute better performance since it exhibited better performance in rise time and settling time as well as producing small percentage of overshoot and lower readings for RMSE, IAE, ISE and ITAE.

ACKNOWLEDGEMENT

Firstly, I wish to thank God for giving me the opportunity to embark on my PhD and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor Assoc Prof Ts. Dr. Mohd Hezri Bin Fazalul Rahiman and my co-supervisor Dr. Mohd Hezri Bin Marzaki.

My appreciation goes to the Ts. Dr Mazidah Tajjudin who borrowed the pilot plant and assistance during sampling. Special thanks to my colleagues and friends for helping me with this project.

And, this thesis is dedicated to the loving memory of my very dear mother, and late father, Allahyarham Haji Md Shariff Aziz for the vision and determination to educate me. This piece of victory is dedicated to both of you.

Finally, for my beloved wife Nor Azian Abd Rahim for giving me unmatched lovely support in finishing this journey. For my three jewels Muhammad Ammar Syafiq, Nur Husna Maisarah and Muhammad Amir Isyraf for shining my journey with their unconditional love. Alhamdulilah.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Essential oils are such oils that are concentrated, hydrophobic, containing hundreds of aromatic compounds constituents, and rich with hormones, vitamins, and other natural elements [1]. These compounds can be extracted from leaves, stems, flowers, bark and roots from a botanical raw material via any techniques of extraction [2]-[6]. In 2020, the global essential oils market size was valued at USD 18.6 billion and is expected to expand at a Compound Annual Growth Rate of 9.7% in terms of revenue from 2021 to 2028 [7], [8]. This is driven by the increasing demand from major end-use industries such as food and beverage, pharmaceuticals and cosmetics, and aromatherapy [9]—[13]. The essential oil contains highly volatile components but clean for the environment [14]. There is no side effect to the users compared to conventional medicines and drugs [1], [12], [15]. Due to the increasing demand of essential oils, countless research efforts in improving its extraction techniques have been reported [16].

In order to produce essential oils, several techniques such as steam distillation method, superheated water extraction, supercritical fluid extraction, solvent extraction, and subcritical water extraction are used [1], [2], [7], [10], [30], [44], [45], [49]. Despite these many techniques, temperature control is the most important when it comes to achieving the best quality of oil as small error will otherwise degrade the quality of the chemical structure composition [33], [34]. Most classical methods in essential oil extraction were done with less supervision when it comes to temperature control, in which the temperature is left unmonitored and deviates from the desired set point up to several degrees [33], [35], [36].

The steam distillation technique is still relevant for industrial and research purposes despite its age. The low production and maintenance cost, energy efficiency, cleanliness (green environment), and higher oil yield are the main reasons it is still popular nowadays [26], [29], [37], [38]. The temperature control technique of steam distillation essential oil extraction process directly affects the quality and quantity of the product [36], [39].