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LabVIEW Venus Flytrap ANFIS Inverse Control System for Microwave Heating Cavity

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Abstract
Growing interests in nature-inspired computing and bio-inspired optimization techniques have led to powerful tools for solving learning problems and analyzing large datasets. Several methods have been utilized to create superior performance-based optimization algorithms. However, certain applications, like nonlinear real-time, are difficult to explain using accurate mathematical models. Such large-scale combination and highly nonlinear modeling problems are solved by usage of soft computing techniques. So, in this paper, the researchers have tried to incorporate one of the most advanced plant algorithms known as Venus Flytrap Plant algorithm(VFO) along with soft-computing techniques and, to be specific, the ANFIS inverse model-Adaptive Neural Fuzzy Inference System for controlling the real-time temperature of a microwave cavity that heats oil. The MATLAB was integrated successfully with the LabVIEW platform. Wide ranges of input and output variables were experimented with. Problems were encountered due to heating system conditions like reflected power, variations in oil temperature, and oil inlet absorption and cavity temperatures affecting the oil temperature, besides the temperature's effect on viscosity. The LabVIEW design followed and the results figure in the performance of the VFO- Inverse ANFIS controller.

Keywords
Venus Flytrap Algorithm, ANFIS, Microwave, LabVIEW.

I. INTRODUCTION

Numerous studies and books have been written on nature-inspired optimization algorithms [1–7] that have proven highly effective in solving a wide variety of optimization problems. These algorithms are typically rooted in swarm intelligence, such as the Darwinian evolution and natural selection of biological systems utilized by genetic algorithms. Various mathematical operators, such as crossover or recombination, mutation, fitness and selection of the fittest, are employed. Additionally, some algorithms are based on insects, including bee colonies, a, firefly, and glowworms, as well as animals such as birds, bats, monkeys, lions, and wolves. Each of these algorithms boasts unique advantages and perspectives on how to best solve optimization problems, including neural networks, genetic algorithms, particle swarm optimization, bacterial foraging algorithm, shuffled frog leaping algorithm, flower pollination algorithm, and artificial plant optimization algorithm.

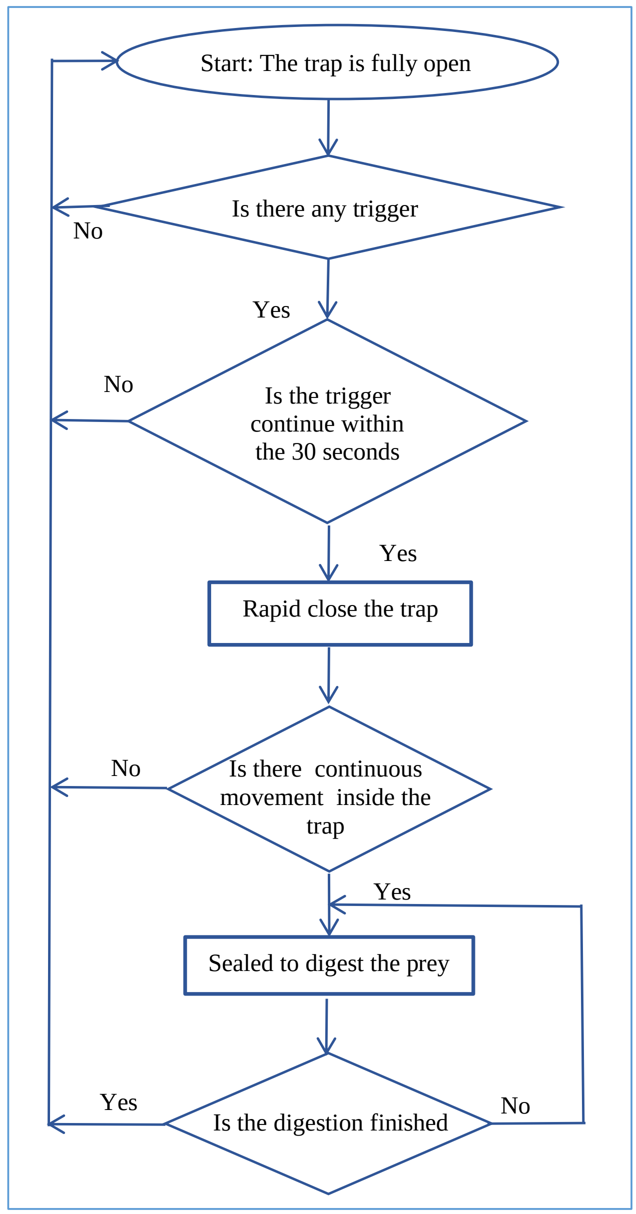
One of the latest meta-heuristic algorithms is the Venus Flytrap Optimization (VFO) algorithm, which takes inspiration from the survival strategies of plants in nature. This algorithm is based on the rapid closure behavior of the Venus Flytrap's leaves, which possess two heart-shaped lobes complete with hairs on their surface. The Venus Flytrap has three states of movement [8]: fully open, semiclosed, and fully closed. These states are illustrated in Fig. 1(a). The trap operates by going through three phases: trigger, tightening, and re-opening. Once the prey is inside the trap, it causes the tightening of the trap. However, if there is no movement inside the trap, then the prey escapes and there is no sealing phase. Additionally,

if the prey is not caught fully and damages the trap, it will not be sealed, and the trap will be reopened. The algorithm flowchart for the Venus Flytrap can be seen in Fig. 1.
Researchers have utilized the closing mechanism of a Venus flytrap [9]. Esser, et al. [10], have provided a comprehensive overview of the recent advancements in flytrap-inspired soft machine systems, focusing on principles of motion. Amany, et al. [11]proposed algorithm Venus Flytrap Optimization (VFO), for solving numerical optimization problems. Experimental analysis is implemented on some benchmark functions to show the performance of the proposed algorithm.
The goal is to combine a smart Venus Flytrap Flower algorithm with an inverse ANFIS model for microwave heating cavity and to integrate it with LabVIEW and MATLAB. LabVIEW uses a graphical programming language to visualize applications, whereas MATLAB is a computer programming language that focuses more on numerical functions. LabVIEW is more focused on working with computer hardware, and it is easy to connect different pieces of hardware on the platform because of its graphical interface. In comparison, MATLAB may require more work to interface with hardware, but as a platform, it does support a wider range of equipment, making it more versatile. Integrating MATLAB with LabVIEW enables the complete reuse of MATLAB code which is used in this paper to build the inverse ANFIS that mimics the real-time microwave heating cavity. as shown in Fig. 2.

II. Real Time Continuous Flow Microwave Reactor

The benefits of heating in the different chemical processes, which use the microwave in an increase the reaction rate with short time, and improve the product purity compared to conventional heating. On another side, continuous flow heating has shown benefits over batch heating mode in terms of environmental impact, efficiency, and safety [12]. Combining microwave heating with the continuous flow technique creates a promising way to scale up microwave-assisted syntheses [13]. Precise parameter control is the key to yielding the target with better purity and selectivity.So, relatively small quantities are present in the microwave cavity using continuous flow allowing for better heating exchange and faster response on parameters adjustments and regulations for control signals.There are many types of continuous flow microwave reactors [14], like normal tub, Ω tub, U tub or spiral tubes, and so on. Some times used a mixed tube [13]. There are several papers, which reported on continuous flow microwave reactors in different.

(a)



(b)

Fig. 1. (a) Venus Flytrap Flower, (b) The Venus Flytrap Algorithm Flowchart.

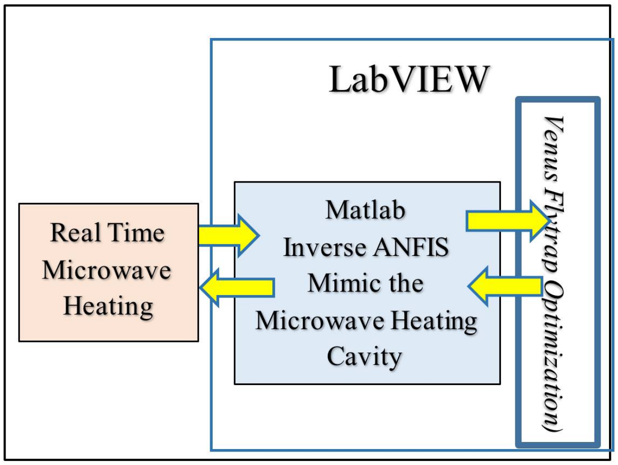


Fig. 2. Integrating MATLAB with LabVIEW

scales [15]. Fig. 3 illustrates the real time continuous flow of oil within coil in the microwave cavity, and it is clear that the cavity parameters can be controlled.The experimental data [16] in Fig. 4 provides a comprehensive overview of the microwave cavity, including the inlet and outlet temperature, inflow rate, delivered power, reflective power, and outlet temperature, making it extremely useful for system modeling. With this data, the ANFIS model can accurately reflect the cavity's behavior.

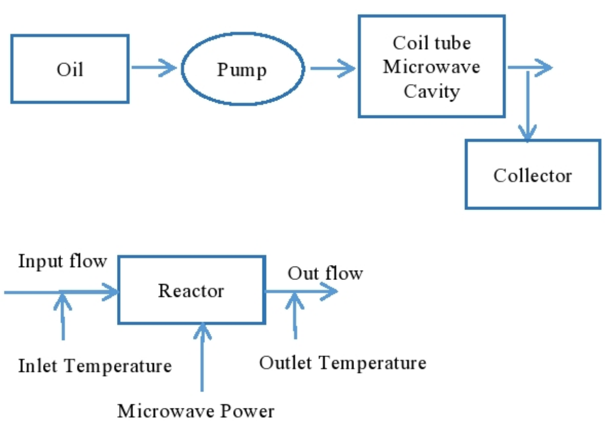
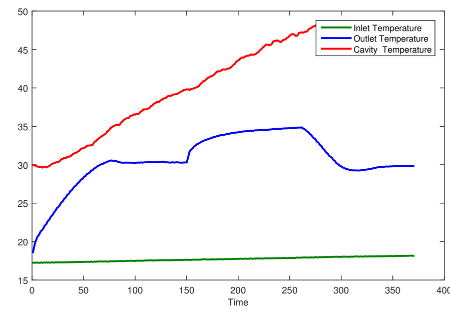


Fig. 3. Continuous Flow Rector

III. Inverse Adaptive Neural Fuzzy Inference System (ANFIS)

The ANFIS model principles, initially proposed by Jang in 1992 [17] have emerged as a highly effective approach for generating fuzzy IF-THEN rules with appropriate membership functions based on input-output pairs. Recent studies demonstrate that ANFIS outperforms classical models when provided with sufficient information to construct fuzzy rules. Additionally, the ANFIS inverse model controller provides a straightforward method for controller design, where the controller functions as the inverse of the plant [18]. Despite the advantages of ANFIS inverse controllers, several challenges may impede their performance, such as model uncertainties, measurement noise, and the absence of sufficient training parameter data.



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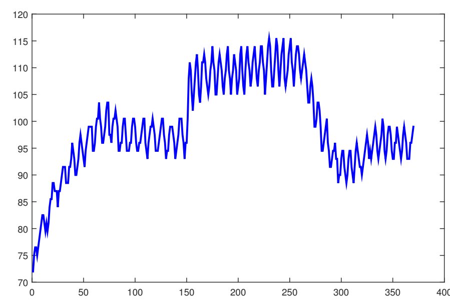

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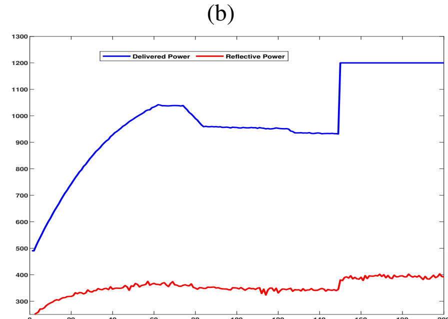
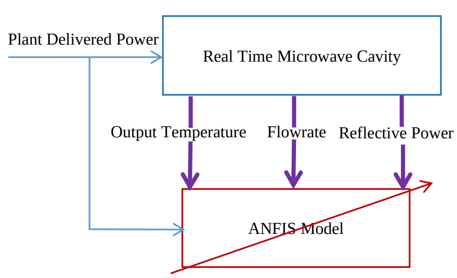


(c)

Fig. 4. Microwave Parameters (a)(Inlet , Outlet, and cavity temperatures)C, (b) (Flowrate) ml/sec , (c) (Delivered and Reflective Powers)Watt.

To overcome these challenges, researchers have adopted various techniques, including modified ANFIS inverse learning methods and adaptive ANFIS inverse controllers.Overall, the ANFIS model and its inverse controller have proven to be promising tools for a range of applications, including control engineering, robotics, and data mining. Further research in this area will undoubtedly lead to even more advanced methods for addressing the challenges associated with ANFIS inverse controllers and expanding the scope of their applications 19.
The ANFIS inverse network and VFO algorithm operate in tandem to capture real-time microwave oil heating temperature errors. By emulating real-time systems using ANFIS and ANFIS inverse models, we can effectively address narrow errors without inducing any uncertain system behavior stemming from high nonlinearities. This proposed method proactively eliminates errors offline by forecasting appropriate parameter changes in the system based on present operating conditions. Such a technique can facilitate the prediction and updating of system parameters to achieve desired results while mitigating any negative consequences that nonlinearities may cause and maintaining system stability. Fig 5 exhibits ANFIS parameters, training data, and ANFIS output. ANFIS training was carried out using the MATLAB software in conjunction with LabVIEW.



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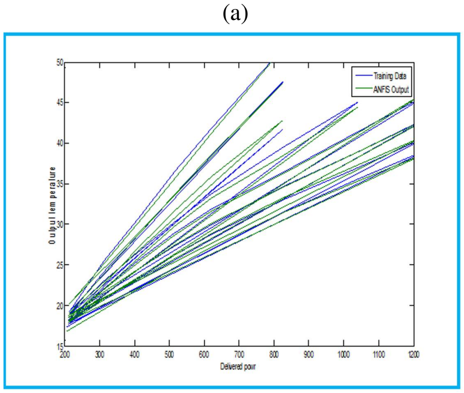


(b)

Fig. 5. (a) Adaptive Neural Fuzzy Inference (ANFIS) model, (b) Training data.

IV. Venus Flytrap-Anfis Control System

In this section, it is explained the Venus flytrap -ANFIS Control System as following:

A. Artificial Venus Flytrap Control Algorithm

As a common basis for a comparison nature and the artificial VFO algorithm for real time continuous microwave flow reactor system describe on Fig. 6. The known observation is that the real-time continuous flow reactor system operates under constant monitoring and often triggers alarms indicating errors and needs to be automated and dealt with quickly to prevent instability. However, the techniques which deal with the error may lead to instability special if the techniques face high non linearity with rapid action. The different states of the system, including open, semi-closed, and closed, can be used to detect the existence of errors and take action to correct them when they cross certain thresholds. By capturing the error at a second the inverse ANFIS controller can be used to update the system parameters and resolve the error occurrence offline and then passed it online safely without any hard transient action that may lead to instability.

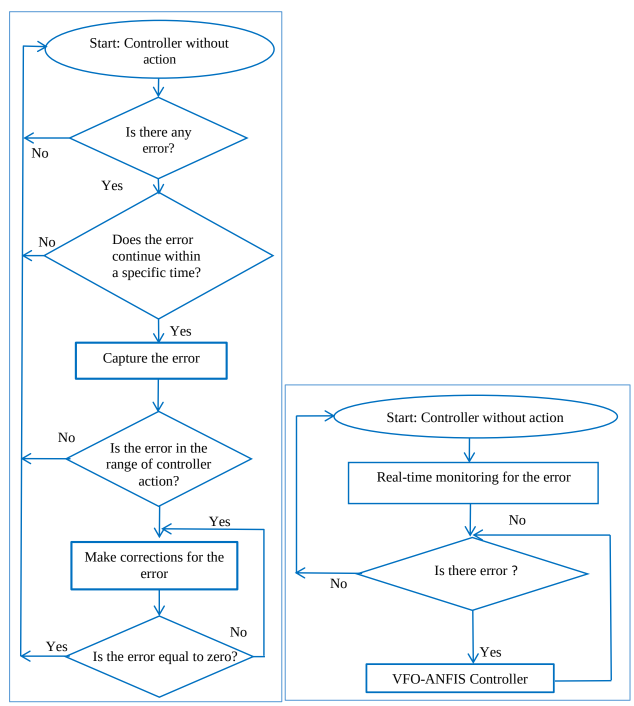


Fig. 6. Artificial VFO algorithm for real time continuous microwave flow reactor system

B. Controller Design

After achieving the final ANFIS model design that takes into account the reactor medium and the microwave applicator, the next step is controlling the process accurately. Both temperature and power control are necessary to proceed under controlled conditions. However, measuring the delivered power is quite rare, and most equipment only provides a value of the input power and sometimes a global value of the reflected power. Therefore, in this paper, the power supply is the main component under control consideration, leading to temperature control. The aim of the controller is to provide the closest possible value of delivered power match to the required setpoint temperature. The reactor cavity contains a continuous flow of oil, which is subject to many parameters that can affect its temperature. There are various disturbances and noises that can cause the temperature to fluctuate, making it difficult to maintain a stable degree. As seen in Fig. 4, the oil flow contributes to the cavity temperature, while the reflective power is a crucial factor in determining the amount of power received by the reactor. Moreover, the heat exchange with the oil is dependent on the viscosity and type of oil used. The block diagram of the closed-loop system controller is shown in Fig 7, while fig. 8 shows the controller flowchart describing the controller steps. With this controller, it is possible to maintain the required temperature and power conditions, making the process more reliable and efficient.

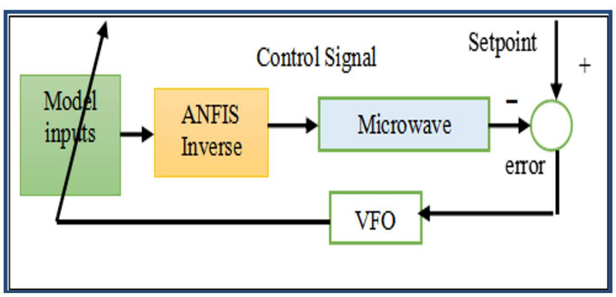


Fig. 7. System under closed loop controller.

C. LabVEIW Controller Implemented

The microwave system monitoring system is an advanced platform based on LabVIEW technology. The LabVIEW front panel program is designed with various control structures and data displays, making it easy for users to monitor and manage the system. The block diagram is composed of various function modules that enable data collection through sequential structure, conditions of the structure, and the form of the while loop. Users can read, write, and call C language source code and call the dynamic link library directly, allowing for the combination of many programs with LabVIEW. Fig. 8 and Fig. 9 displays the system's front panel and block diagram.

As mentioned in the paper, ANFIS was implemented in Matlab and appointed as part of LabVIEW. To implement VFO sequence as in controller flowchart shown in Fig. 10 , users can use the Flat Sequence Structure, and Case Structure as shown in Fig. 11.

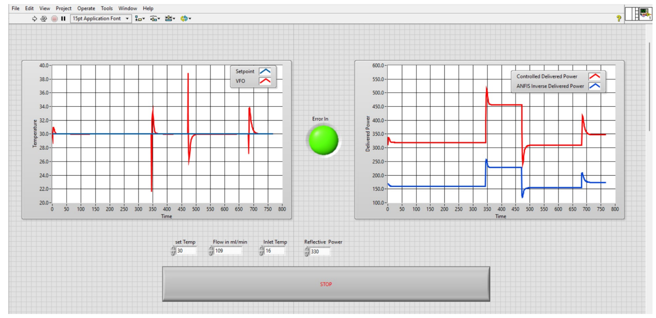


Fig. 8. LabVIEW front panel of the proposed controller.

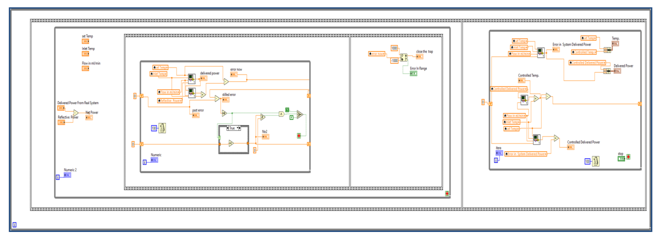


Fig. 9. LabVIEW block diagram of the proposed controller.

D. LabVIEW Controller Implemented sequences

Fig. 11 are declares the controller design sequences:
First stage: The monitoring of the output temperature in real-time, keeping a close on any changes above or below the setpoint, or sometimes, it's necessary to adjust the setpoint itself in order to maintain optimal temperature levels. Fig. 12 (a) illustrates the error monitoring process scenario.
Second Stage: Analyzing the error in range or not, as shown in Fig. 12(b). If the error has a large value, it is essential to drop the error to be within the range of the controller. There are several ways to achieve this, such as reducing the reflective power in the microwave tuning section. Once the error is within the controller range, the controller can move on to the next stage.
Third Stage: Fig. 12(c) ANFIS model and the ANFIS inverse model controller work together to initiate and process control action and send the signal to the real-time system.

V. Results and Discussion

The effectiveness of the control depends on the accuracy of the mathematical model. Thanks to artificial intelligence techniques that allow for modeling any system as a black box based on its experiment data, even nonlinear systems can be perfectly mimicked using an efficient algorithm like ANFIS with VFO algorithm that allows the updating and prediction in confined regions around the error, which makes it easy to deal with and gives a good result. The performance of the proposed VFO_ANFIS inverse model has been widely examined, as shown in Fig. 13 for set point changes, Fig. 14 for inlet temperature changes, and Fig. 15 for flow changes. The controller demonstrates excellent performance, effectively automating a complex heating system with nontraditional temperature control. All of the controller evaluation parameters indicate that it accurately reflects the set point applied, with good rise time, settling time, and steady-state error.

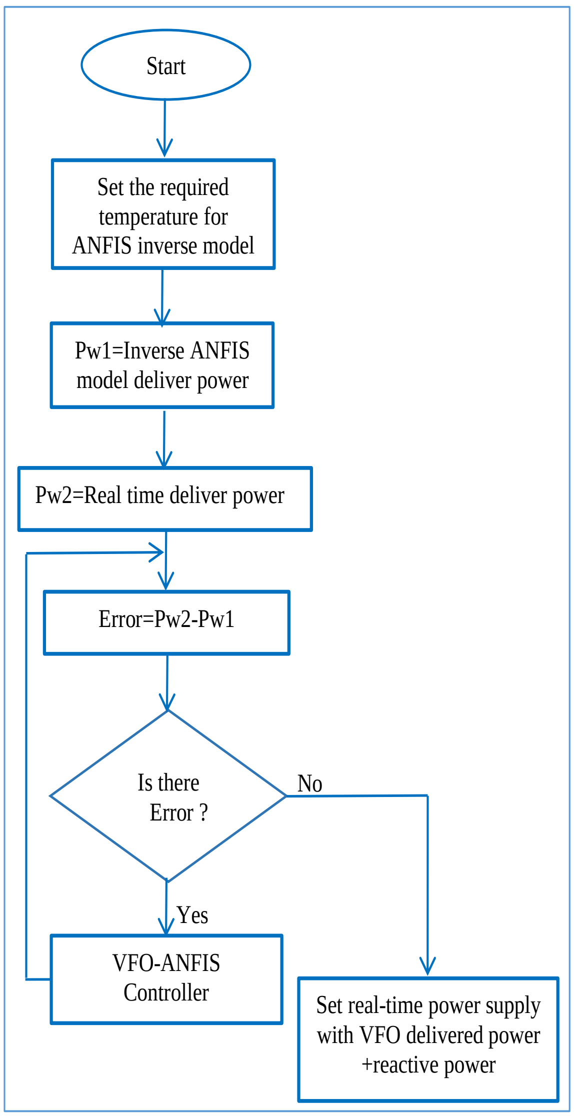


Fig. 10. Controller flowchart.

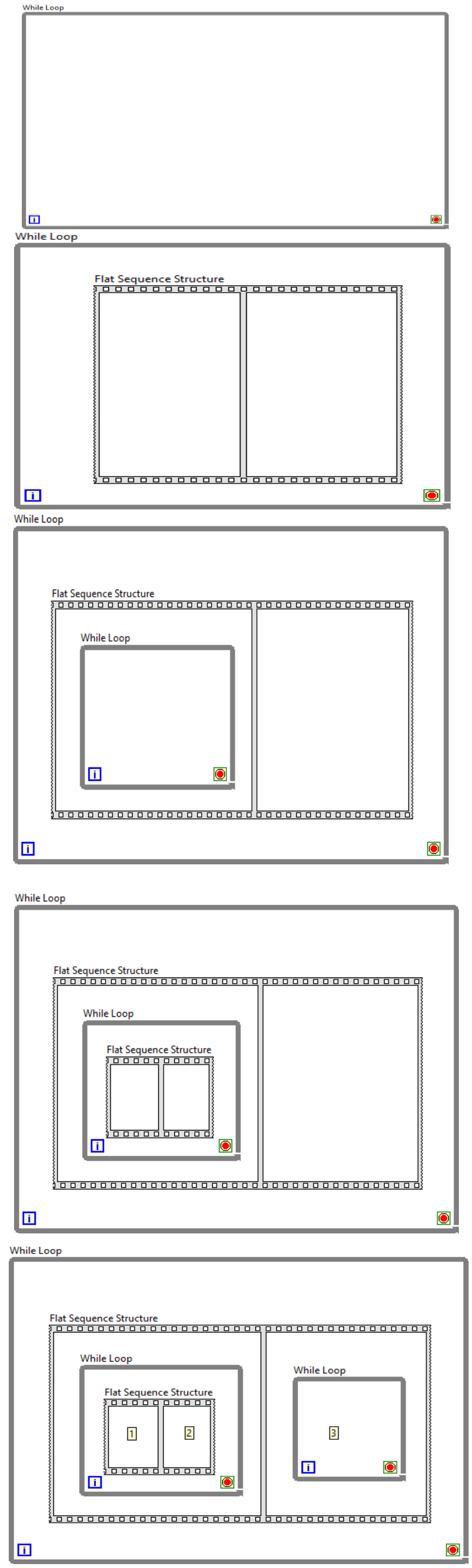
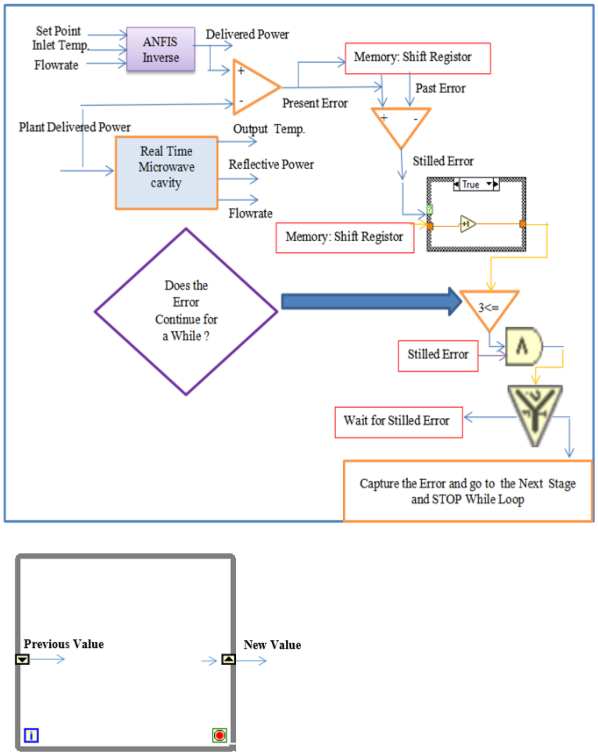


Fig. 11. Sequence structure and case structure.



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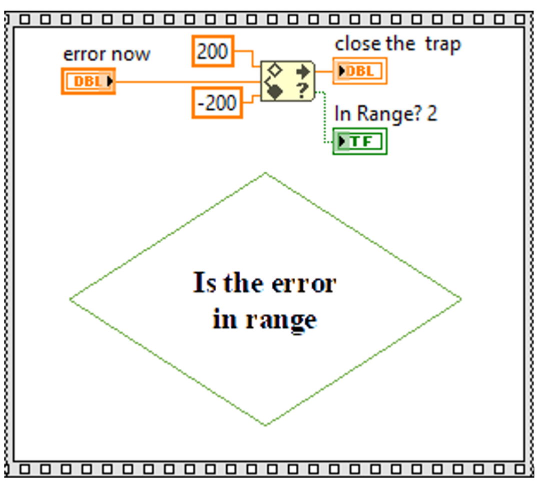

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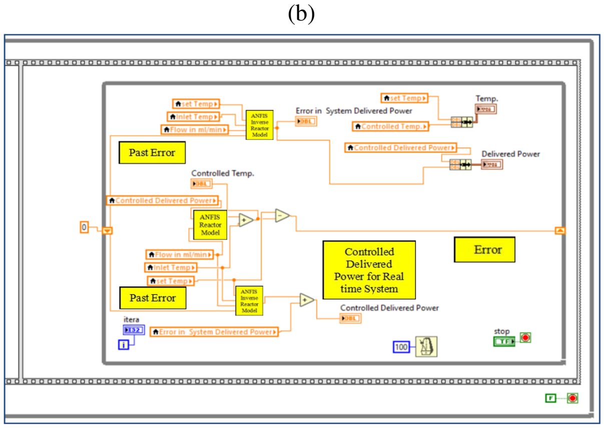
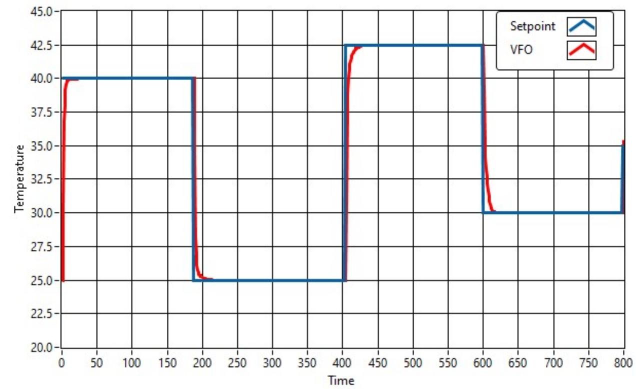
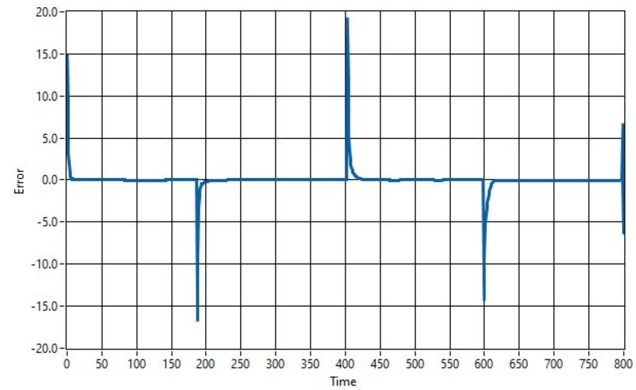


(c)

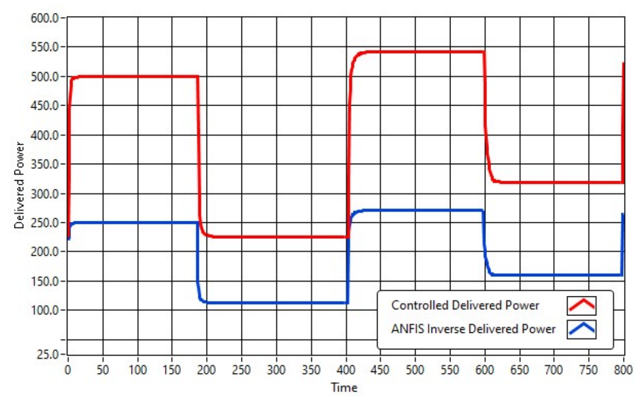
Fig. 12. Three stages for proposed controller.



(a) Setpoint changing.

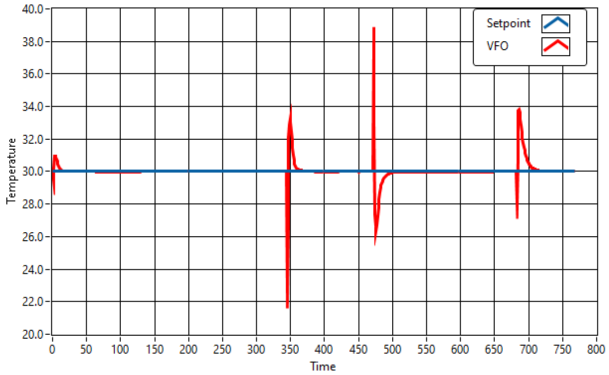


(b) Errors at setpoint changes.

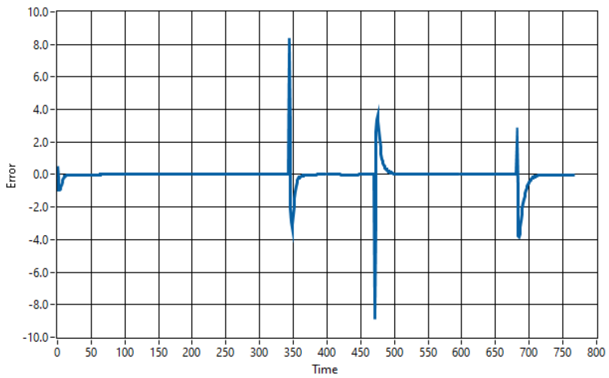


(c) Delivered power at setpoint changes.

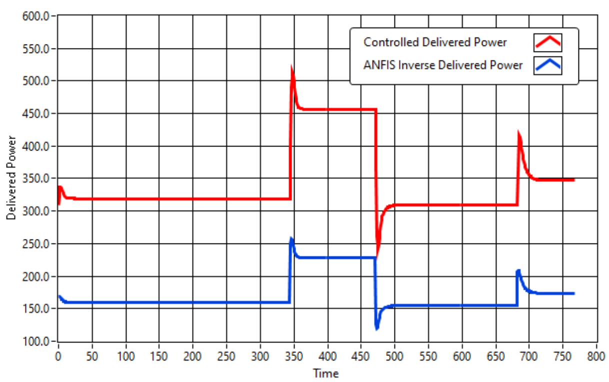
Fig. 13. Controller response at setpont changing, flowrate 109ml/s, inlet Temperature17.5, reflective power 330 W.



(a) Output Temperature changes at inlet temperature.

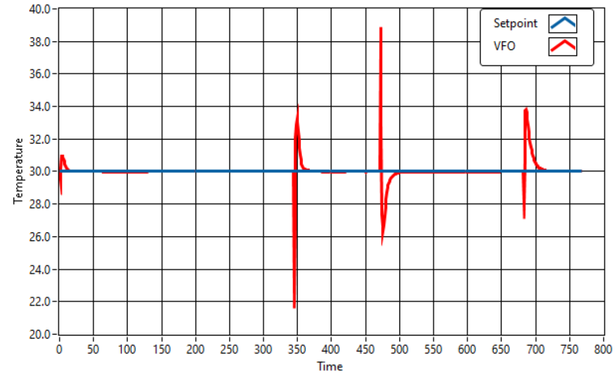


(b) Errors at disturbance rejection.

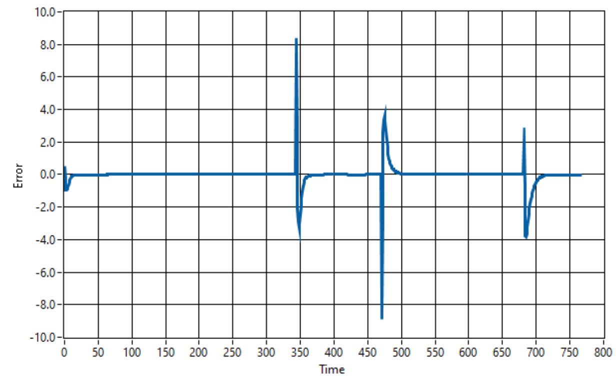


(c) Delivered power at disturbance rejection.

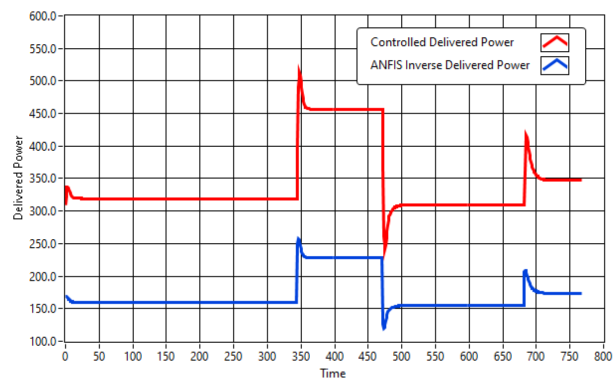
Fig. 14. Controller response at inlet temperature changing (17.5,10,18,16)flowrate109ml/s,reflective power 330 W.



(a) Output Temperature at flowrate changes.



(b) Error at changing flowrate(Disturbance rejection).



(c) Delivered power at flowrate changes(Disturbance rejection).

Fig. 15. Disturbance rejection: flowrate changing (109, 93, 110, 96) ml/sec, ,inlet temperature 17.5 C, reflective power 330 W.

VI. Conclusion

In this paper, the Venus Flytrap algorithm has been designed based inverse ANFIS system model. VFO technique has been used to discover the error and capture the satellited one the passed it to another stage that ANFIS inverse act offline control signal to avoid unsuitability. Experimental data was used to design ANFIS and inverse ANFIS microwave reactor as heating system model and controller. LabVIEW and Matlab software used based on a set of parameters such as delivered power, reflected power, inlet temperature flowrate and outlet temperature. It can be seen that the results demonstrate that the controller is capable of tracking different reference signals, rejecting disturbances, and achieving good performance without compromising the system's stability. This is achieved by compensating for the differences between the real system and the ANFIS model, which can be affected by reflective power.

Conflict of Interest

The authors have declared no conflict of interest.

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