An Intelligent Temperature control system for a Prototype Greenhouse based on IoT Technology

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Abstract *In recent years, the Greenhouse has been developed with the latest technologies due to the importance of this field. The aim of this paper is to design and implement an intelligent controller for cooling / heating system, using an efficient and low power consumption device, called Thermo-electric cooler (Peltier).*

The goal of the main controller is to stabilize the temperature inside the greenhouse. A fuzzy controller is designed based on two inputs, error (Err) between set point and actual temperature, and change in error (ΔErr), and one output (pwm) which act as a control signal to drive the Peltier. The overall system is built based on a standalone microcontroller with a simple sensor and actuator.

an IoT system are Implemented to enable the farmer to monitor the greenhouse temperature and change it remotely, that for make the peasants works much easier and save much efforts.

The prescribed system is tested with some experiments using different transition set point. The result of these experiments shows accepted responses that are suitable for greenhouse applications.

Keywords**: Greenhouse Technology, Internet of Things, Temperature Control, Fuzzy Controller, Thermo-electric cooler.**

I. Introduction

Greenhouse is a structure with different type of covering material, like glass or plastic roof and walls. It is heated up due to the incoming solar radiation of sun that absorbed by plants, water, and everything inside the structure.

Greenhouse is a building for agricultural purposes to provide suitable conditions for plants, likes temperature, water, and light. The purpose of this work is to build an intelligent cooling / heating system to achieve the desired temperature for greenhouse[1].

The IoT is driven by an extension of the Internet through the incorporation of physical articles joined with a capacity to give more quick-witted administrations to the earth as more information ends up noticeably accessible. Different application areas going from Green-IT and vitality effectiveness to coordination's are now beginning to profit by Internet of Things ideas[2].

Many researchers propose different ideas in this field, emphasizing on heating by using tools like heaters, heating tower, and fans.

M.Thakor, et.al. introduce their paper about using Peltier in cooling by using PID and Avalanche Photo Diode (APD) for sensing the temperature. Their system depends on the error to control the Peltier using integrated thermo-electric cooling (TEC) controller MAX1978 [3].

S. Dai, et.al. were suggesting low-cost, simple method for intelligent fan motor. This method uses the Atmel AT89S52 microcontroller chip and a few periphery components as a control system. This works in two modes, in the first mode, the temperature is sensed and accordingly, change the fan's speed, while in the second mode a remote infrared that aimed to achieve the same goal [4].

A. Montoya et. al. suggest to combine two heating system forced-air heaters, and pipe systems which usually used separately because the difficulty in control, they proposed to combine them and control on it by new way hybrid controller [5].

Sivakumaran et. al. a proposed temperature control system based on fuzzy logic principles, the idea implies using a heating device to take the temperature in the greenhouse and update the control signal that control the heater. This works is supported by simulation result [6].

R.Grigoriu, et al their idea include using parabolic trough collectors (GHPTC) to heat the greenhouse, In spite of the GHPTC have some disadvantages. Their work heats the fluid and passes it through a collector pipe. Their work is tested by both simulation and real implementation using PID to accomplish control and automation of temperature inside the greenhouse [7].

In 2015, L. Dan *et al.* presented their paper that centered on using the CC2530 as core chip and introduces a monitoring system design for greenhouse depends on the ZigBee technology. A terminal node sends the temperature to intermediate node by the wireless network, and this node collects all data and sends them to the PC[8].

J. Zhao *et al.* proposes a paper that studies the integration of control networks and information networks in IoT in practical agriculture production. They also suggest a method that combines the remote monitoring system and wireless communications[9].

The main idea of the proposed system is to facilitate the task of the peasants to monitor and control the temperature of the greenhouse remotely, in addition to preview the scene inside the greenhouse using IoT technologies.

II. Thermo-electric Cooler (Peltier):

The Thermo-electric Cooler (TEC) is an electronic device contains P and N type organize one opposite the other, when the current applied in specified polarity of voltage the result is that side will become very warm and the other very cold [10]. As illustrated in Fig. 1.

Peltier has many advantages like simple structure, no moving parts, high precisions, stability, and quick response. Peltier is small size and very low weight. In spite of these advantages, Peltier suffered from several problems, including low thermal power, low efficiency, and high cost of TEC controller.

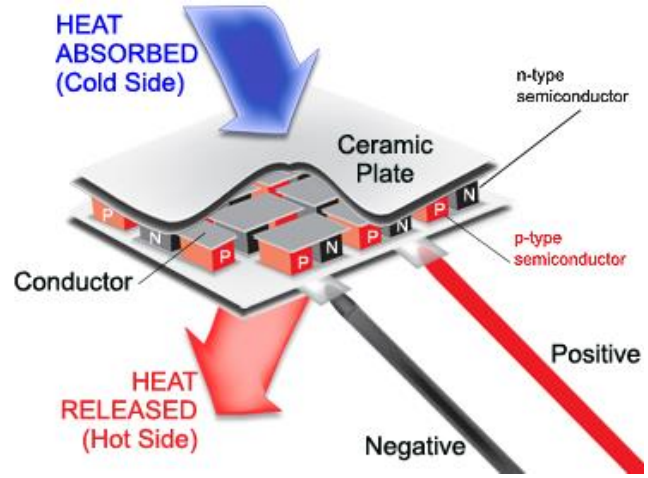

Fig. 1 Peltier work.

III. The IoT Technology:

In recent years, a large number of IoT interest papers have been published. IoT acts as the main role in technology development. The IoT introduces numerous facilities in any field that may use it. This paper focusing on using IoT in the greenhouse as previously explained, the proposed greenhouse had intelligent temperature control systems. The function of IoT in this work gives the farmers the ability to monitor and control their greenhouses remotely.

To make the work of IoT easy to understand, Fig. 2 gives the imagination about how the IoT work in upload and download data and deliver it to the control systems.

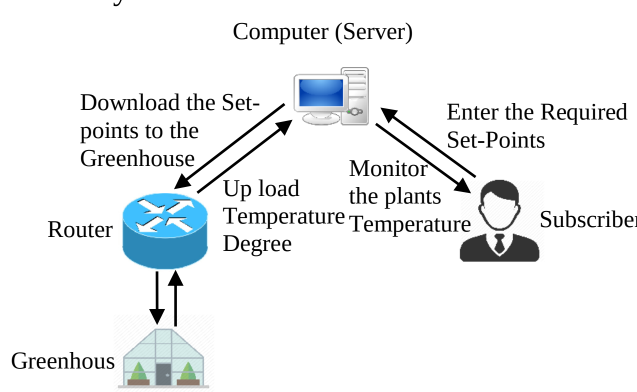

Fig. 2 The Proposed IoT system

To achieve an IoT system that can perform the functions described in figure in Fig. 2, there are some programs and techniques should be employed:

A. the Connection of System to the Internet:

Frequently, cloud servers are utilized to hold the web application of the IoT services to enable the users to access such application from anywhere and at any time. In this work, a local server was prepared to do such services in order to reduce the overall cost in addition to eliminate the need for system security. Hence, a public IP is required to make the server globally available, which adds the public IP lease cost. So, in order to go beyond all the above restrictions,

The Dynamic Domain Name System (DDNS), port forwarding technique, and Virtual Server (XAMMP) are employed in this work.

The first step is getting DDNS from some companies that provide such services like NO-IP, DDNS, etc. This enable the people to access their local router (Gateway) from anywhere after setting up the DDNS inside it as depicted in Fig. 2.

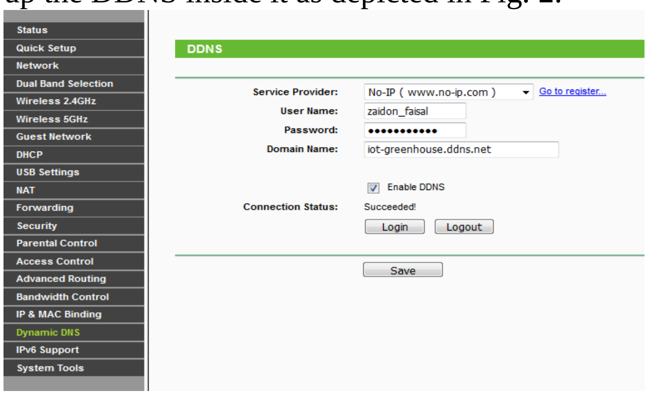

Fig. 2 Setting the DDNS in the Router.

Then should ties this link (between the user from anywhere to the local router) with the virtual server (Computer), install the virtual server (XAMPP) on the computer and gives a unique port number as illustrated in Fig. 3.

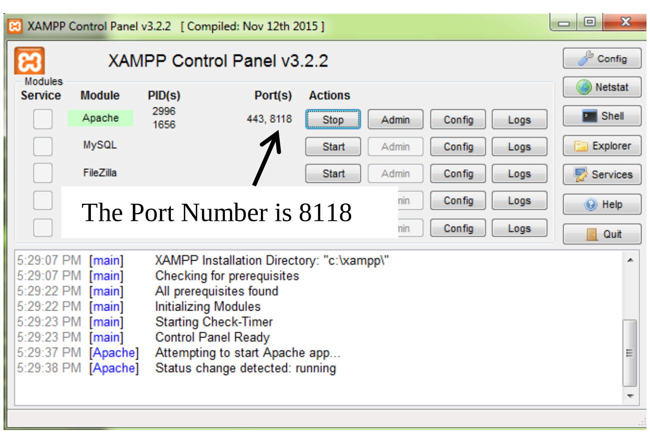

Fig. 3 Virtual Server Configuration and the Port Number.

Then using the port forwarding technique that existed on the router to forward the packets over this link to the virtual server depending on the IP of the computer and the port number of the virtual server that reside inside the computer as shown in Fig. 4.

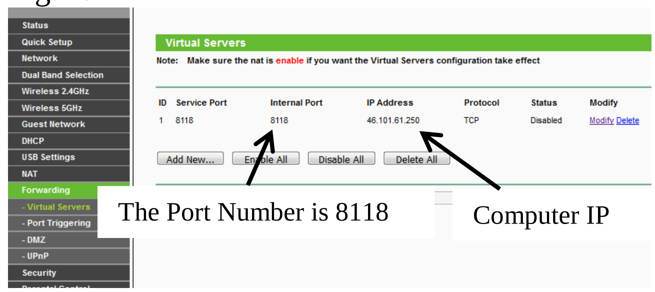

Fig. 4 The Port Forwarding and the port number.

After completing this configuration, the web-application that resides in the computer in the local network should be accessible from anywhere.

B. Remotely Management and Monitor the system's status.

In this article, attempt to construct a prototype IoT, using simple, cheap, and available tools. To apply the IoT in a practical application, there are many tools should be employed like Ethernet Arduino Shield and Arduino microcontroller.

The Ethernet plays as the main tool which makes a connection between the greenhouse and the router which acts as a gateway. The first step was programming the microcontroller to construct a link between the greenhouse and the server, this link try to reach a specific PHP file existed on that server. The PHP file function fetches the data that send over the link from the greenhouse and store it on a MySQL table (database). The link established by HTTP request, which is issued by the microcontrollers.

The download data could be accomplished by requests multiple HTTP initiated by the microcontroller that exist on the Greenhouse to the server. The response of the server has returned the intended data to the source (microcontroller) of the request. The microcontroller will receive the server's response and store it in buffers, then start to looking for the intended parameters that used for managing process. This set-point utilize to drive the intelligent Cooling/Heating control system and by this way satisfied the remotely management.

III. The Proposed Cooling/Heating System:

The proposed system design is divided into two parts; hardware and software. The proposed approach includes the design of control circuit that receives control signals generated by the implemented fuzzy controller, which reside completely in the microcontroller, and use it to drive the Peltier. As shown in Fig. 5:

A. *Control Circuit*

Figure 6 depicts the proposed main control circuit that controls the Peltier current to change the temperature and change the polarity to select (heating or cooling).

The upper part of this circuit is used to reverse the voltage polarity of the Peltier using two relays, while the lower part is utilized to control the applied voltage to the Peltier to regulate the desired temperature.

To drive the operation of this circuit, a microcontroller is used for this purpose.

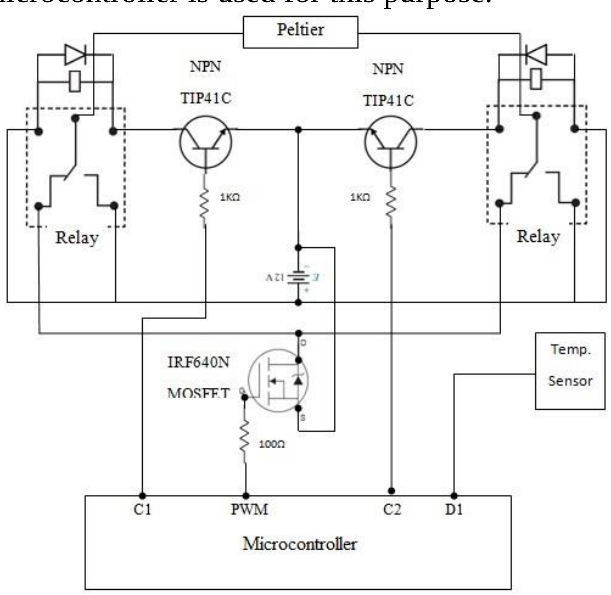

Fig. 6 Polarity and Voltage control circuit

When C1 high and C2 low, the Peltier gives cold air.

This circuit is important because the Peltier work on 12VDC, this circuit feed the Peltier +12VDC and -12VDC to run Peltier for cooling and for warming, the control signal come from Arduino 5V.

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The Mosfet IRF640N is added in the lower part to regulate the applied voltage to the Peltier. A pulse width modulation (pwm) signal is generated by the microcontroller to accomplish the regulation process.

B. *Software Design (Fuzzy Controller)*

In order to drive the control circuit, fuzzy system is designed with two inputs (error and change of error) and one output (pwm).

The universe of discourse of both inputs is (-10 ~ +10) and (-5 ~ +5) for error and change of error respectively, Both are divided into five triangle membership (NB, NS, Z, PS, PB) function. As shown in Fig. 7 and Fig. 8 respectively.

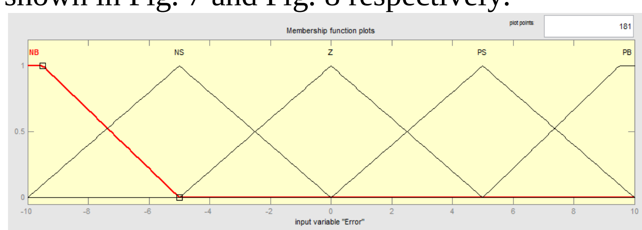


Fig. 7 Membership functions of Error.

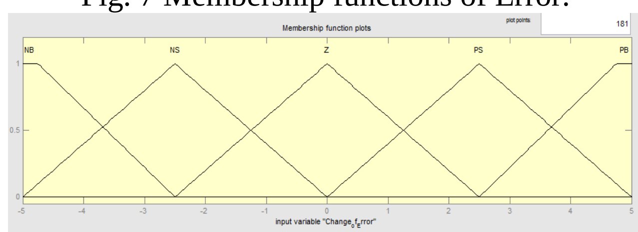
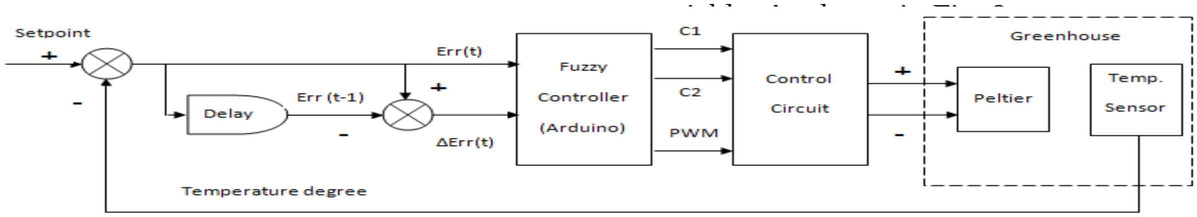


Fig. 8 Change of error membership function.

The output universe of discourse is between (-255 ~ +255) which is divided into five linguistic



When C1 low ar

warm air.

. Fig. 5 The Block diagram of the proposed design.

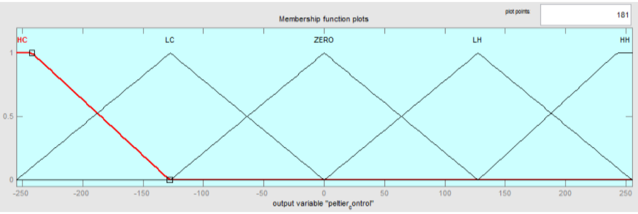


Fig. 9 The output membership functions of the fuzzy control system.

As shown in Fig. 9, the output may be positive or negative, that because the system need to recognize if the required action is cooling or heating, that to indicate the right polarity of Peltier to heating when the output was positive cooling when the fuzzy output was negative.

The rules that represent the inference engine are designed according to the system behavior which is shown in Table1.

Table1: Rules Table

Err \ ΔErr	**NB**	**NS**	**Z**	**PS**	**PB**
NB	VH	VH	VH	H	Z
NS	VH	VH	H	Z	L
Z	VH	H	Z	L	VL
PS	H	Z	L	VL	VL
PB	Z	L	VL	VL	VL

IV. Flow of operation

Refer to the flowchart of Fig 10, the control operation starting by downloading set-point of temperature from the server, and use it to calculate the error and change of error (Err, ΔErr), which are the inputs of fuzzy controllers. According to these inputs, the fuzzy controller makes a decision, which is either cooling or heating, via (c1 and c2); in addition to the amount of required pwm signal.

The signals (C1 and C2) are used to activate the relays that are used to select the proper voltage polarity applied on Peltier, while the pwm output is used to regulate the amount of applied voltage using Mosfet IRF640N.

In order to protect the Peltier from damage, due to fast polarity change, a time delay is inserted when there is a polarity change is required. This delay is selected to guarantee that the two surfaces of Peltier are equal temperature before applying the new polarity.

Then sense the temperature degree inside the greenhouse and upload it to the server in order to enable the subscriber to monitor the greenhouse status.

IV.Results of the proposed system

The previous work is implemented in real and tested. The dimensions of the structure of the greenhouse are Length is 60 cm (1.9685 feet), the Width is 40 cm (1.31234 feet), and the height is 40 cm (1.31234 feet) as shown in Fig 11.

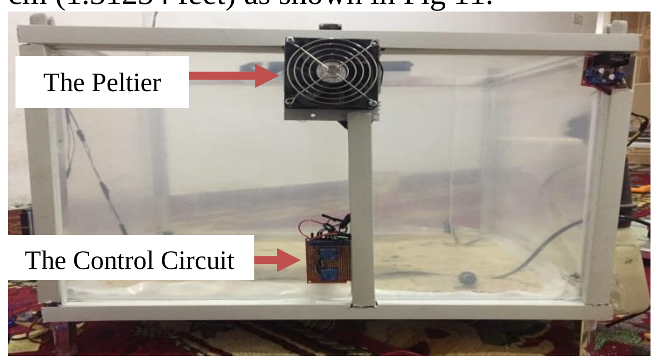


Fig.11 the Prototype of Greenhouse

In order to demonstrate the overall system results. A MatLab/Simulink is designed for this purpose, due to the shortage of microcontroller abilities in drawing graphs.

Fig. 12 shows the Simulink structure to read the temperature from the sensor in order to be plotted.

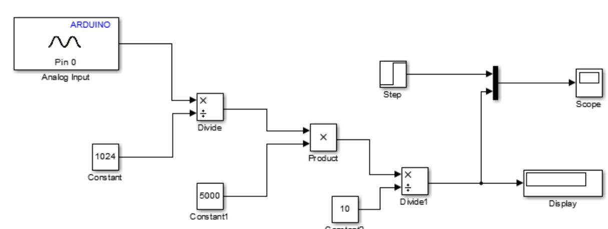


Fig. 12 MatLab/Simulink to draw a response of the system.

Wiring the lm35 temperature sensor with an Arduino microcontroller and download the Simulink structure which shown in Fig. 8 in Arduino and utilize the synchronization between

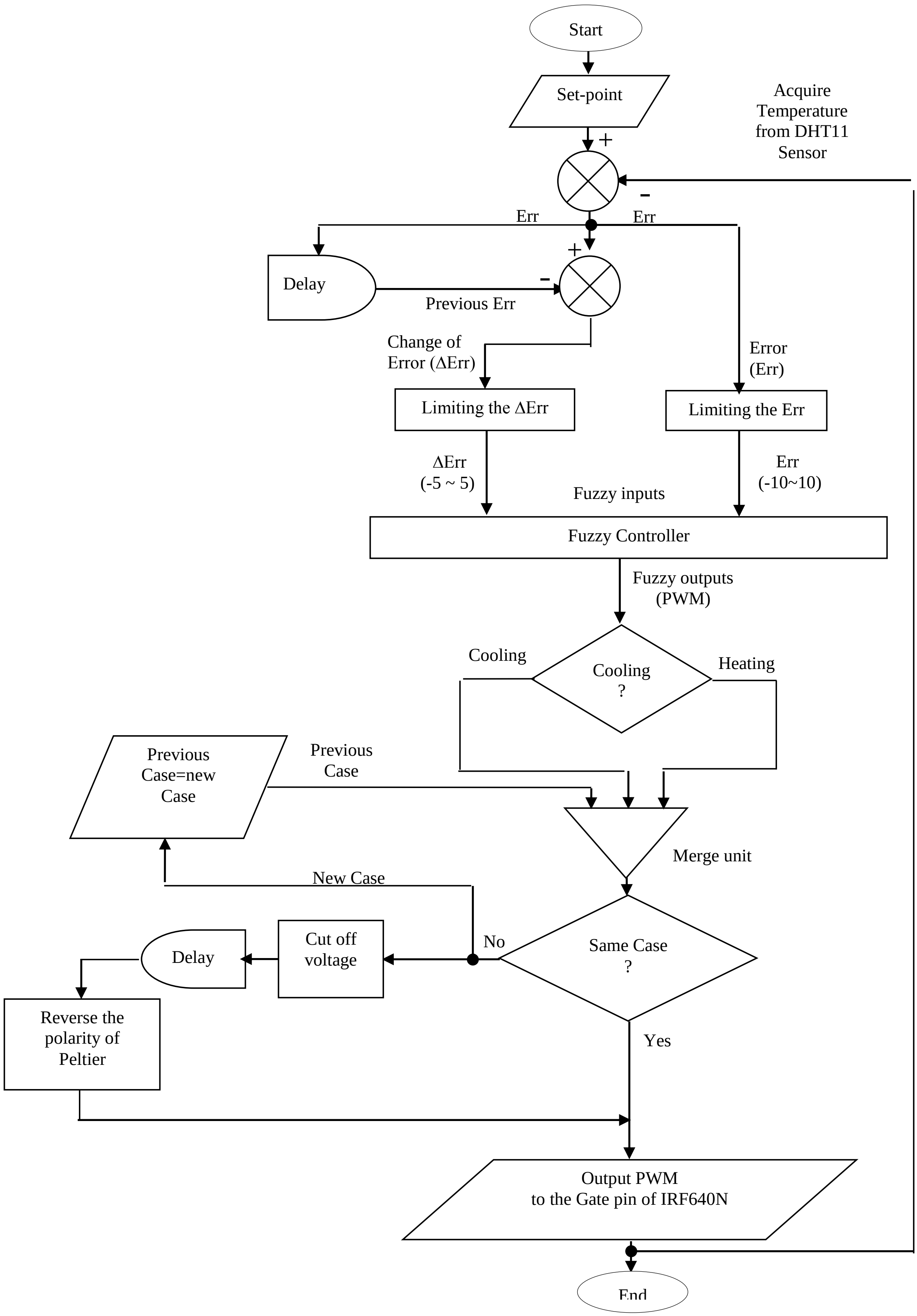


Fig. 10 Cooling/ Heating Flow operation.

the MatLab/Simulink and the Arduino in order to plot the temperature readout.

The system is tested with different initial and set value of temperature. Some experiment starting with the high initial value and asked to reach a lower set point, while the others are starting with low initial values to reach a higher set-point.

These set-points have been settled remotely by the Web-application as Fig. 13. And by trial figure out the time required to download the data from the web application to the microcontroller is about 450 msec and the time to upload the temperature degree from the microcontroller to the server is about 950 msec.

Fig.14 shows different system experiments that verify the system performance.

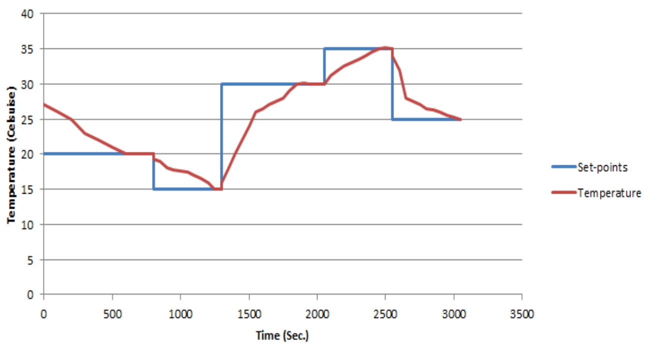


Fig. 14 The system performance under different set-points.

It is clear from Fig.14, that in all experiments the set point is captured in an acceptable time period.

- First including set point 20° C and must give knowledge of current temperature without any effect is (25° ~ 28°) C.

The required action is cooling. So, apply the correct polarity on the terminal of the Peltier, then output the PWM on IRF640N to pass the correct value of current to the Peltier.

- The second set point is 15° C, the starting temperature degree is about 20° C. This case requires cooling action as well; compute the value of PWM to pass the suitable current to the Peltier.

- The third set point is 30° C, and the current temperature is 15° C. the require action is heating, the current case (Heating) is different from the previous case (Cooling), to avoid the Peltier damage should follow this instruction in transition case:

    i. Cut voltage off from delivering to Peltier.
    ii. Wait until the both sides of Peltier have the same temperature, then out correct polarity, then out pwm to produce the suitable voltage on the Peltier.

- The Fourth set-point is 35° C, and the temperature is about 30° C.

The action is heating, which is the same previous action, directly output the pwm to produce the correct value of the Current on the Peltier.

- The fifth set point is 25° C, the current temperature is about 35° C.
The action is cooling, for that should follow the procedure of reverse the polarity, then output suitable value of the PWM to pass the correct value of current to the Peltier in order to produce the suitable value of cooling that to satisfy the set-point.

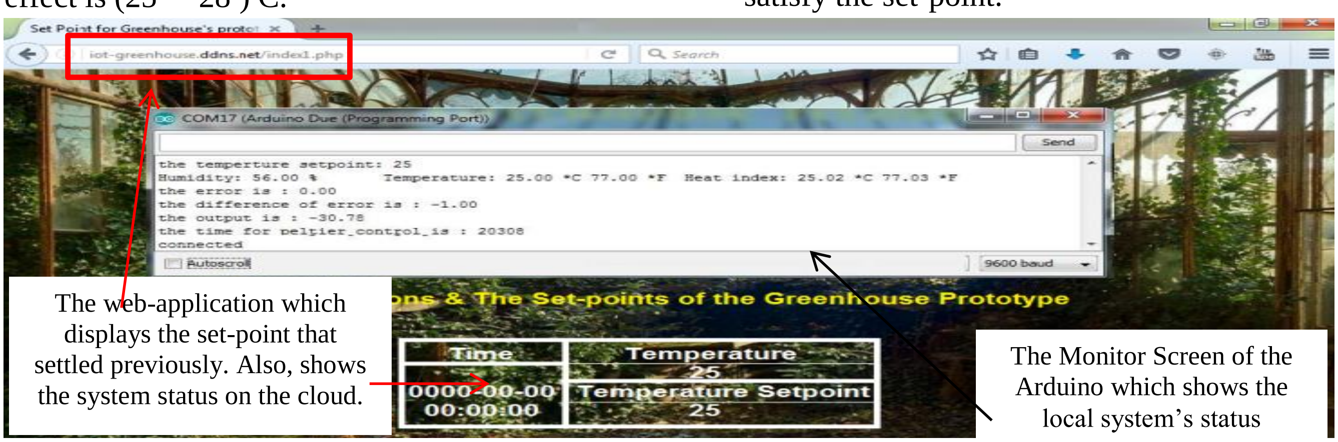


Fig. 13 IoT performance and Web-Application

In order to shows the high performance of this system, the system's response should be compared with other work's result. For that, the reference [3] has shown the system's response when the temperature equal to 30° C and the settling to 25° C. the system satisfied it in 430 second approximately. This work satisfied the temperature transition from 35° C to 25° C in the same period as shows previously in Fig. 14.

V. Conclusions

The resulting system is stable, low cost, and low power consumption that because the thermo-electric cooler, which is a very useful tool that have no mechanical parts and numerous advantages. The proposed electronic circuit contains simple tools as transistors and relays, and diodes in order to derive the Peltier in an efficient manner. The control circuit is controlled the Peltier to producing either heating or cooling according to signals that generated by a fuzzy controller, which depend on two inputs, error (the difference between the desired temperature and the actual temperature) and change of error (the difference between the current error and previous error), which reside completely in microcontroller without require for any external processing. The IoT system make the work of the farmers much easier by enable them to monitor the greenhouse temperature and change the set-point of the temperature control system remotely. This gives the system the practicality, robustness, and high performance. The system was test with different transition some experiments started with a low initial value and raise the temperature inside the greenhouse, and some experiments start with a high initial value and decrease the temperature inside the greenhouse. In general the proposed system can stabilize the desired temperature inside the greenhouse and that contributed to provide suitable circumstances for plants.

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نظام ذكي للتحكم في درجة الحرارة داخل نموذجا من البيت الزراعي بالاعتماد على تقنيات انترنت الاشياء

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الخلاصة في السنوات الاخيرة، تقنية البيوت الزراعية تم تطويرها بادخال اخر التطورات التقنية وذلك لاهمية هذا الموضوع. تهدف هذا المقالة الى تصميم و بناء متحكم ذكي يسيطر على نظام التبريد/التدفئة، باستخدام جهاز كفوء و ذات قدرة واطئة، يدعى*Thermo-electric cooler (Peltier)* .

الهدف من المتحكم الرئيسي هو تثبيت درجة الحرارة داخل البيت الزراعي. المتحكم المضبب تم تصميمه بلاعتماد على ادخالين: الاول يدعى الخطأ (Err) وهو الفرق بين درجة الحرارة المرجعية و درجة الحرارة الحقيقية داخل البيت الزراعي، اما الادخال الثاني هو التغير في الخطأ (∆Err)، كذلك النظام يحتوي على اخراج واحد (pwm) والذي يستخدم كاشارة سيطرة للتحكم في Peltier. النظام تم برمجته داخل المتحكم بشكل كامل مع استخدام بعض المتحسسات و المتحكمات بالمحركات.

نظام انترنت الاشياء تم تنفيذه وذلك لتمكين الفلاحين من مراقبة درجة حرارة البيت الزراعي و تغييرها عن بعد، وذلك لتسهيل عمل الفلاحين و تقليل الجهودهم المبذولة.

النظام الذي تم وصفه مسبقا قد تم فحصه ببضعة تجارب باستخدام درجات حرارة مرجعية متنوعة. نتائج هذه التجارب تظهر بان النظام يعطي نتائج مقبولة وتناسب تطبيق البيت الزراعي.