Automated gas-controlled cooker system design and implementation

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ABSTRACT

Cooking from ancient times has evolved from using open fires to wood, gas cookers, using liquefied petroleum gas (LPG). This has also come with various adverse effects ranging from gas leakages to burnt food due to absent-mindedness, thereby creating a significant disaster that could lead to loss of life and property damage. The study aimed to reduce the rate of liquefied petroleum gas related accidents in domestic usage and improve the safety of domestic gas users. An automated method to enforce safety was proposed to avoid unwanted cooking gas flow consequences, especially in homes. The paper presents a control system using an Arduino Uno with a control design interfaced with a utensil sensor, solenoid valve, and a timer circuit to allow gas flow to commence and ignite a flame automatically. The automatic ignition apparatus, which has a high-voltage electric circuit, begins to function once the utensil detector comes in contact with silverware. The system is designed to function in different modes to ensure safety and prevent gas flow. The prototype serves as a means of curbing gas wastage and increasing the safety of people who use LPG as a source of fuel for cooking.

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1. INTRODUCTION

Our ancestors often left fires burning for long periods as the ability to start a fire which was a skill on its own. The cooking process was on open fires on bare ground [1]–[3]. Later on, people introduced simple masonry construction to hold the cooking utensils in place [4]–[6]. Bread and other products were made in primitive ovens by the ancient Greeks [7], [8]. Higher brick and mortar stone walls, frequently with chimneys, were created by the Middle Ages. Cooking food was typically placed in metal cauldrons suspended over the fire [9]. Wood-burning furnaces were mainly created to limit the quantity of smoke emitted.

Fire chambers were built, with holes bored into the ceilings to allow cooking pots with flat bottoms to be placed directly on top of the cauldron when replacing the wood fuel. Other options have been developed over time to reduce cooking labor with better efficiency such as kerosene stoves. The kerosene design has downsides over the prior cooking process, such as smoke, soot, and explosions caused by adulteration or leaking. Liquefied petroleum gas (LPG) came on board as another alternative for cooking

(cooking gas) [10]–[12]. Although LPG is considered cost-effective, burns without producing smoke, and is soothing when used, it is more prone to an explosion due to leaking and is more difficult to confine due to its gaseous nature [13]–[16].

Another issue with conventional gas is that absent-mindedness or forgetfulness with the cooking of food could lead to burnt food and fire outbreaks. Safety measures such as a pressurized container are utilized to limit its volatility [17], [18]. However, instead of leaking, the most prevalent problem with cooking gas is accidental gas flow. Gas leaks can occur due to a valve malfunction or even pipe leaks, which repairs can only contain. This unattended/unintended gas flow issue develops when the knob/valve regulating the cooking gas flow is opened and left without ignition to start the fire [19], [20]. The likelihood of an explosion in the presence of a spark increases as the gas concentration in an area rises, as a result, if left to accumulate and a spark is introduced, an explosion ensues, destroying lives and properties [21].

Lack of knowledge, forgetfulness, arsonist motives, and minors' abuse could contribute to accidental gas flow [22]. Rivera *et al.* [17] designed an automated gas leakage detection system using a thermistor to trigger an alarm once a fire outbreak is detected. Other researchers who worked on automatic gas leakage detection systems include the authors [23]–[25]. Many research works have been published on gas leak detection systems, timing, and temperature control of electric cookers, but there is still no substantial work on timing control to control LPG gas flow, hence this paper aims to design and implement an automated gas-controlled cooker system that prevents unwanted gas flow with several means of control.

2. METHOD

The proposed system gas cooker controls are completely automatic with no human intervention. The prototype is based on the design of an automated gas flow regulator used during and after cooking. The system will produce a fire once it detects the presence of a utensil on the gas burner. The technology automates the closure of the gas flow valve once a cooking utensil is put on top of the cook-top and there is no spark to ignite the flame. Upon completion of cooking, the gas flow automatically ceases by closing the valve when the utensil is removed from the burner.

The system is also designed to extinguish the flame by ceasing gas flow when the set/desired time is reached. The design includes timer elements to stop the gas flow and algorithms to make intelligent decisions based on sensor readings. The methodology used here incorporates the step-by-step assembly of the needed components to achieve the feasibility study of the target design.

2.1. System units design

The system design comprises the development and integration of the hardware and software that makes up the system. The hardware consists of the physical devices or electronic circuits used during the system's construction, including the microcontroller unit (MCU), load sensor unit, timer, light-emitting diode (LED) display unit, gas flow control unit, and power supply unit. The software design includes the computer programming of the microcontrollers using the microcontroller's source code. The software was created on a computer system using the Arduino sketch and then uploaded to the Arduino board through a USB port [26].

The system design is such that the solenoid valve regulates the gas flow line once it receives electric signals from the microcontroller. Figure 1 shows the flow chart of the interaction between the hardware and software units for the overall system operation. The system's design framework and circuitry were carried out using the fritzing software. Figure 2 gives the circuit diagram of the system design operation.

2.2. System operation

The Arduino Uno microcontroller is the most critical and controlling unit that acts as the system's brain. The power supply unit provides the required voltage to power the entire system. Once the sensor on the burner detects the presence of the utensil on it, the signal is read on the input pin of the microcontroller. When the display LED turns white, the user can now select his/her desired time via the timer knob, and then depress the push button. Once the push button is depressed, its pin connected to the microcontroller reads 0v since it's an active low switch.

The signal passed from the push button to the microcontroller prompting the microcontroller to trigger the relay connected to the solenoid valve, thereby allowing gas to flow through it to the combustion section. Simultaneously, the relay connected to the Ignition module is also triggered, thereby generating a spark. The combination of the spark and the gas forms the flame. The system was designed to operate in two modes, by which the gas flow ceases and shuts down: Once the utensil placed on the cooker top is removed, the system automatically shuts down by turning off the plunger in the solenoid valve to prevent gas flow. Secondly, once the set time runs out, the plunger in the solenoid valve will prevent gas flow.

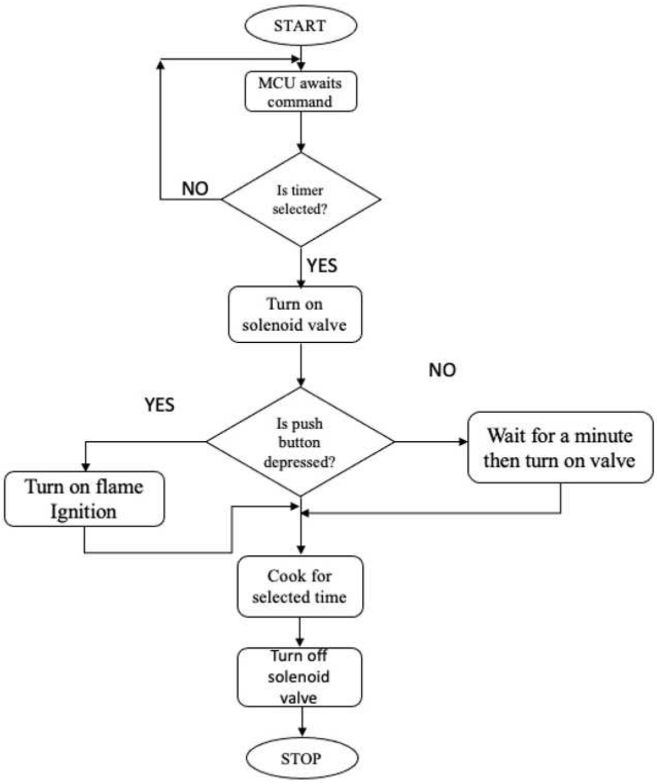

Figure 1. Flowchart of system operation

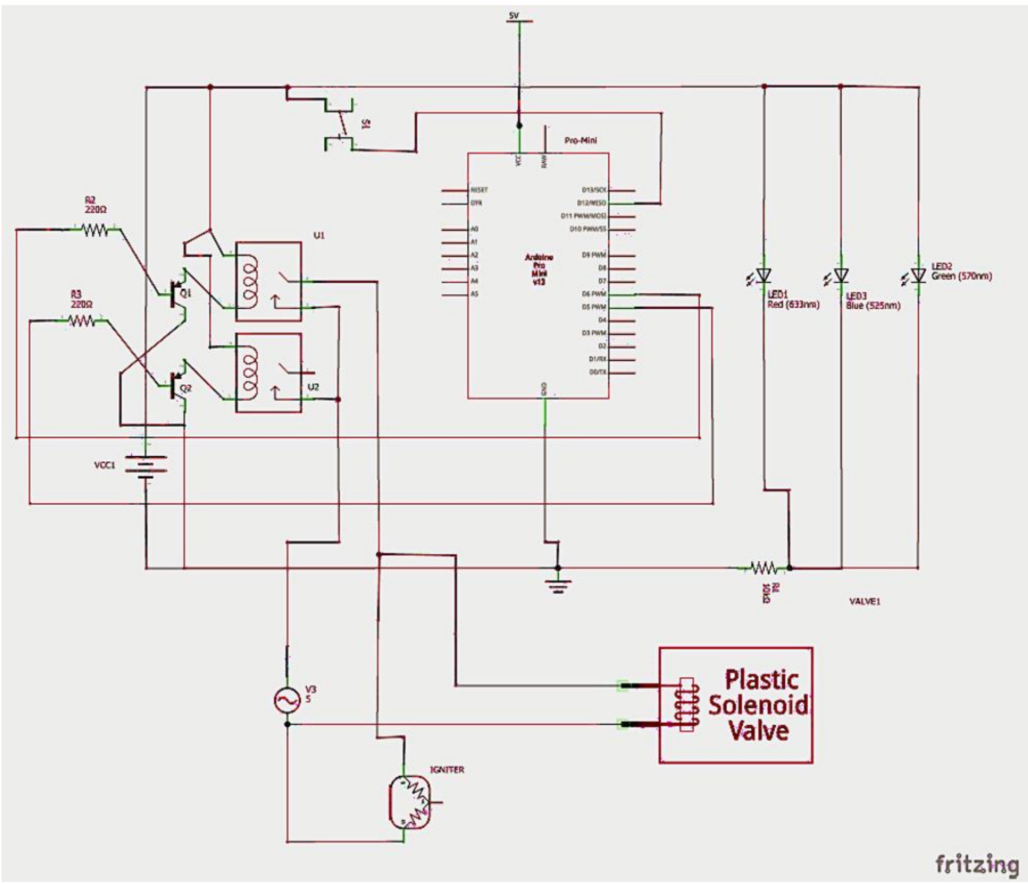

Figure 2. Schematic diagram of circuit

Figure 3 presents the microcontroller connection to the printed circuit board (PCB) in the system operation. Figure 4 shows the connection of the 5 V DC relay to the Microcontroller. Figure 5 presents the connection of the ignition module to the microcontroller. The module has a sparking ignitor with a flame sensor used to generate the spark required to start a fire, it has a BlackBox that converts the 220 V to 16 kV and creates a spark at permittivity of air that is 1. Figure 6 shows the final system design prototype.

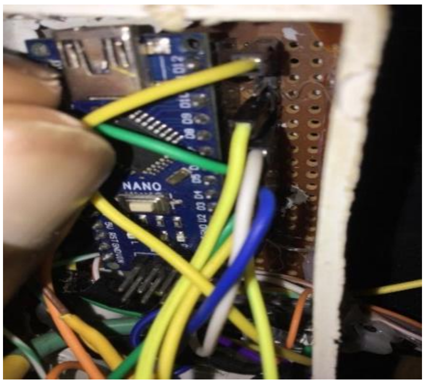

Figure 3. Microcontroller connection to the PCB

Figure 4. Connection of 5 V DC relay to microcontroller

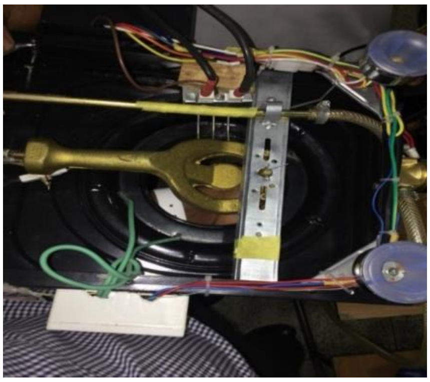

Figure 5. Connection of the ignition module and the microcontroller

Figure 6. Final system prototype design

3. RESULTS AND DISCUSSION

Multiple tests of the system's subunits were conducted to eliminate design and implementation flaws that may have occurred during development and to also verify its proper operation. Since malfunctioning in any part of the system element could damage the system's full functionality, the different critical subunits that make up the system design need to be tested.

3.1. System testing

The entire system was tested to establish optimal complete operating conditions and ensure the operational cycle. The following tests were carried out on the system: The ignition probe test was carried out in such a way that once a utensil is detected, the microcontroller sends a signal, causing the ignition module to generate sparks on the ignition probe located close to the combustion ring. Upon utensil detection and the timer set to the desired time using the timer knob, the ignition probe generates the spark to start the fire, and the gas flow ceases indicating that the time specified by the user has elapsed. Additionally, if a utensil is placed on the burner without a timer set, gas flow is interrupted until the timer push button is depressed.

The Utensil sensor test was also done in such a way that, suppose the timer is set, and the push button is depressed without the utensil on the burner; in that case, there will be no gas flow as the sensor, which is in the form of an open circuit, requires a utensil serving as a switch to close the circuit and send the appropriate signal to the microcontroller to permit gas flow and generate a spark. The LEDs used three different colors; in the design, blue, white, and red colors were used for the LED test. Figure 7 shows a Blue LED indicator, indicating that the cooking operation was done and was successful. Figure 8 shows a Static White LED indicator, indicating that the system is waiting for the user's command. Figure 9 shows a Red LED indicator, indicating an error in the operation, possibly because a utensil was not detected or the timer was not set before the push button was depressed.

Figure 7. Blue LED indicator

Figure 8. Static white LED indicator

The solenoid valve test can also be described as the gas flow test. When all the suitable conditions are met, the microcontroller sends the electrical signal to the solenoid valve, which activates the plunger, allowing gas flow. When this is activated, fire is made as the ignition module generates a spark. If there is no gas flow, the fire will not be ignited. Figure 10 shows flame from the solenoid valve, depicting the functionality of the designed system. The solenoid valve only permits gas flow once these two conditions are met, firstly when a utensil is detected on the burner and, secondly, when the timer is set; upon completing these two conditions, gas flow is permitted, and the flame is ignited. The complete system was tested and carried out, and Table 1 shows the results of the testing.

Figure 9. Red LED indicator

Figure 10. Flame from the solenoid valve

Table 1. Summary of tests carried out

S/N	Utensil sensor	Ignition probe	Solenoid valve	Timer	LED	Flame
1	Off	Off	Off	Off	White	No
2	On	Off	Off	Off	Red	No
3	Off	Off	Off	On	Red	No
4	On	On	On	On	White	Yes
5	On	Off	Off	On	Blue	No

4. CONCLUSION

The world today is evolving every day with new requirements and new technologies being introduced frequently. The automated gas-controlled cooker system was designed to enhance the conventional gas cooker in numerous ways to meet these commercial standards or evolving customer satisfaction requirements. The essence of this project was to reduce the rate of LPG-related accidents in domestic usage and improve the safety of domestic gas users. This was achievable by fusing elements from a standard cooker top with utensil sensors to detect silverware (Utensils) and a timer switch to set the desired time for cooking. The designed system is economically affordable and implementation ensures that no fire will be ignited without a utensil on the cooker top and timer set, and no gas flow is detected. All the significant objectives were met. The system's operation and functionality were tested to meet the design specifications. The prototype introduced a means of curbing gas wastage and increasing the safety of people who use LPG as a source of fuel for cooking. For future research, digital timing circuits to input the exact cooking time could be included in the system design.

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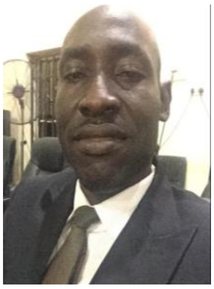

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