Science Journal of Energy Engineering
2024, Vol. 12, No. 4, pp. 91-100
https://doi.org/10.11648/j.sjee.20241204.13

Research Article

Integration of Solar Energy into Fire Safety System

Moussa Ibrahim[1,*], Agbokpanzo Richard Gilles[2], Ir én ée Vianou Madogni[3], Agbomahena Macaire[4]

[1]Laboratory of Telecommunications and Applied Computer Engineering, Abomey-Calavi, Benin
[2]Multidisciplinary Research Laboratory for Technical Education, Higher Normal School of Technical Education, National University of Sciences, Technologies, Engineering and Mathematics, Goho Abomey, Benin
[3]Radiation Physics Laboratory, Physics Department University of Abomey-Calavi, Abomey-Calavi, Benin
[4]Laboratory of Telecommunications and Applied Computer Engineering, Abomey-Calavi, Benin

Abstract

The integration of solar energy into the fire safety system represents a significant step forward in improving the reliability and efficiency of these devices. Traditional security systems generally rely on electricity supplied by the grid, which can be problematic in the event of a power outage during an emergency. Fire has harmful consequences for society, causing human losses and considerable material damage, not to mention the impact on economic activities. To effectively combat this phenomenon, this article proposes the development of an integrated fire protection device, equipped with a solar energy system, guaranteeing energy autonomy and the protection of premises. This device is designed to detect fire outbreaks using sensors. Its design is based on the selection and sizing of various electronic components, including a GSM module, an Arduino Nano, smoke detectors, an alert system, as well as a photovoltaic system for solar energy. For programming and assembly of the electrical circuit, the Qelectrical software is used. In addition, a temperature and humidity sensor is integrated into the alert system, thus forming a control set that ensures the proper operation of the device. Like existing systems, this device helps reduce damage in the event of a fire while operating independently of clean energy sources, respectingthe environment, also meeting the energy needs of the building. It is an ecological, non-polluting solution, suitable even for isolated areas.

Keywords

Fire Protection, Energy Autonomy, Alert System, Solar Energy, Environment, Ecological

1. Introduction

Fire poses a serious threat in many areas, causing loss of life; property damage and significant environmental impacts [1, 3, 9]. Internationally, wildfires are devastating events, resulting in approximately 265,000 deaths each year [1]. Residential fires, in particular, pose a major hazard to life and property in both urban and rural areas. According to studies, these fires caused 73.0% of fire injuries in the United States between 2014 and 2018 and 78.3% of deaths in 2019 in mainland China [2]. In industrialized countries, the majority of fire-related deaths occur in the home, highlighting the importance of fire safety [3]. Fires, even minor ones, can seriously disrupt people's daily lives [4]. Traumatic events,

*Corresponding author: ibrahimmouss21@gmail.com (Moussa Ibrahim)

Received: 1 November 2024; **Accepted:** 15 November 2024; **Published:** 16 December 2024

such as fires, can cause death, injury, and loss of property. Even a small fire can disrupt people's normal lives [5]. Globally, fire prevention programs that promote the use of smoke detectors remain among the most effective strategies for mitigating thisproblem [6]. In this context, fire safety is essential to protect human lives and property. Faced with this situation and the increasing risk of fires caused by climate change and urbanization, the integration of innovative technologies becomes imperative to improve fire prevention and management systems [7]. Solar energy, as a renewable energy source, has promising prospects for strengthening the fire safety system, especially in remote or limited access areas [8]. Figure 1 shows the significant increase that the transition is generating worldwide. towards cleaner and more sustainable energy sources, driven by factors such as technological advances, environmental concerns and supportive policies.

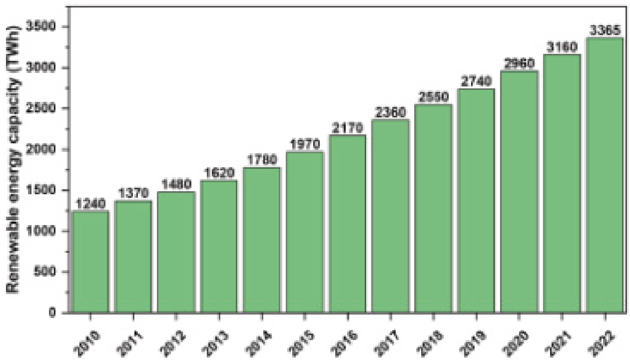


Figure 1. *Global Renewable Energy Adjustment for the Years (2010-2022) [9].*

Traditionally, fire safety systems rely on conventional energy sources, which are often vulnerable to failures in case of emergencies [10]. By integrating solar solutions, these systems can operate autonomously, to ensure continuous availability even during power outages [11]. This energy independence is very important for the management of early warning, detection and fire fighting. In addition, the use of solar energy contributes to the reduction of the carbon footprint of fire safety systems, thus supporting the Sustainable Development Goals [12]. Hybrid systems that support solar energy and other green energy sources can also offer increased resilience to natural disasters [13]. However, the design of such systems must take into account various factors, including reliability, maintenance cost. This theoretical framework highlights the challenges and benefits associated with this integration, by examining existing case studies and technological innovations. The objective of this paper is to propose an integrated design prototype for solar-powered fire safety systems; while evaluating their performance and effectiveness in various environmental and urban contexts. This system aims to quickly detect and report the presence of a fire in a building, reducing the response time needed to implement appropriate safety measures. To do this, the project steps take into account: The development of a synoptic diagram, a detailed study of each component, including smoke sensors and alarm devices [14], the creation of a synoptic diagram to ensure the integration of systems [15], the creation of a functional prototype to test performance [16], verifying the operation of the device through practical tests in various simulated environments [17]. The integration of solar energy into these systems could transform the way fire safety is managed, providing both efficiency and sustainability. This project focuses on the design of a fire safety system associated with a solar energy source, ensuring both energy autonomy and building protection.

2. Materials and Methods

2.1. Methods

Regarding the methodology used, we carried out a documentary research. This research made it possible to list the electronic components and solar equipment used respectively for the design of the fire safety device and to ensure the power supply of the system. References such as the NF S 61-933 standard guided us in the selection of detectors and alarm systems [18]. We sized all these elements in order to have the total power of the device, taking into account the specificities of each component (NF EN 54) [19]. We used the Arduino Uno card for programming, which facilitated the integration of the different sensors. The choice of this card is explained by its flexibility and its large community of users, which offers valuable support. At the same time, the Qelectrotech software was used to establish the electrical diagram, thus allowing a clear viability of the connections and circuits. This software complies with electrical documentary standards, such as ISO 9001, which guarantee good traceability of the installations. We also carried out simulations to validate the operation of the system before its physical assembly. The tests carried out made it possible to verify the reactivity of the smoke detectors in an emergency situation; in accordance with the requirements of the NF S 61-971 standard [20]. Once the prototype was assembled, tests were carried out to ensure that the solar equipment provided a stable power supply. The integration of a backup system, in accordance with the requirements of the labor code, was planned to guarantee continuity of service in the event of a breakdown. Regular inspection reports; as required by the decree of June 25, 1980, were established to ensure the compliance of the installations. We have deepened our research to fully master fire safety [21].

2.1.1. Fire Safety

Fire Safety (FS) is a system installed to detect, react and prevent evacuation in the event of a fire in a building. It is a stand-alone device composed of two devices, also called subsystems: A Fire Detection Device (DPDI); A fire safety device (DMSI). The installation of a fire safety system is governed by the safety regulations or by the safety commission. Depending on the level of fire risk identified, fire safety systems are divided into five classes: type A, B, C, D and E. Type A is the most complete and type E the most basic [22].

2.1.2. Fire Detection System (FDS)

The function of the fire detection system is to accelerate the signals of a fire, either automatically or manually, and consists of: The purpose of the fire detection system is to detect signs of fire, either automatically or manually [23].

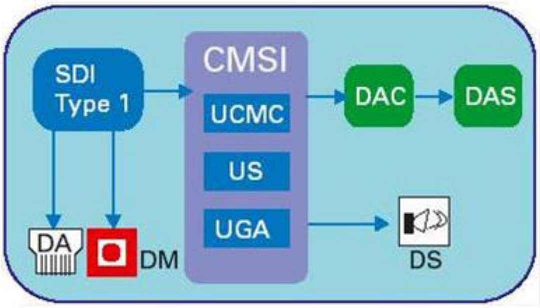


Figure 2. *Example of a Type A fire safety device.*

2.1.3. Automatic Fire Detectors

These round boxes are installed on the ceiling and react to fire signals such as smoke, heating and radiation.

Figure 3. *Automatic fire detector system [24].*

2.1.4. Manual Triggers

These square-shaped boxes, usually red in color, are often located in specific traffic areas, next to exits. They are activated by a person who has observed a fire.

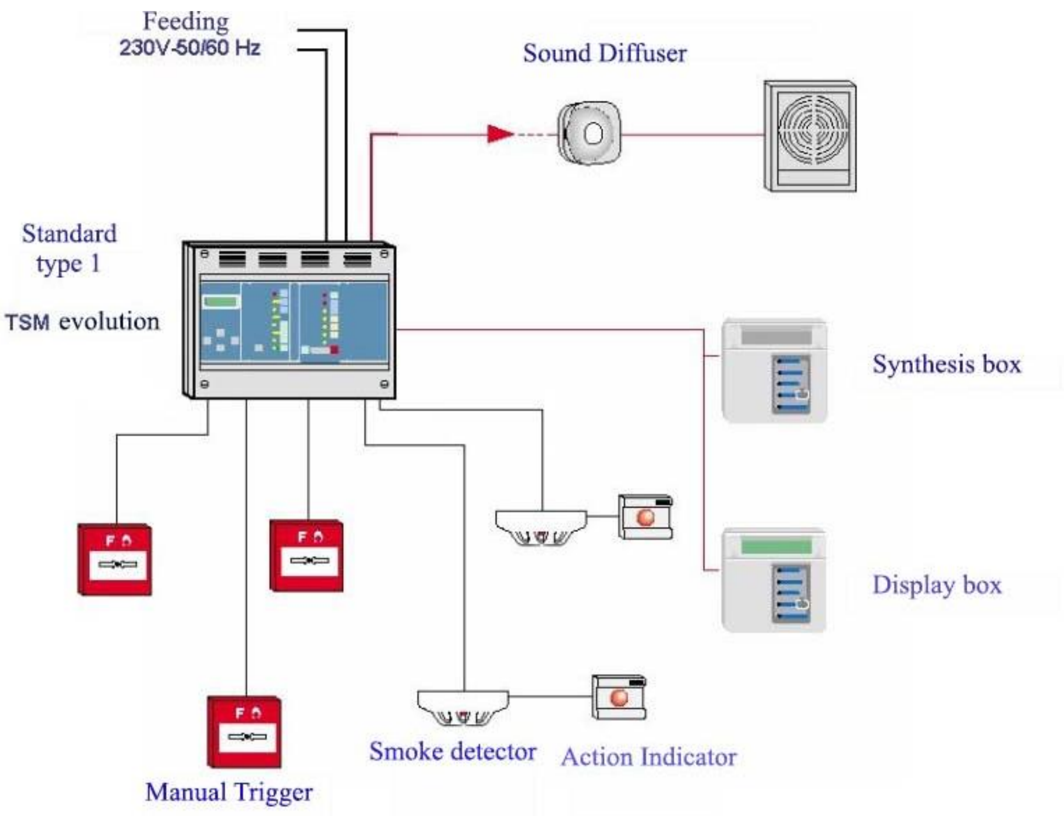


Figure 4. *Manual fire detector system [24].*

2.1.5. Addressable DDI

This technology is generally used for large premises or buildings. It allows precise identification of the fire zone, either on a supervisory computer or on the control panel screen.

2.1.6. A Classic Non-addressable DDI

Cheaper than the previous one. Its technology is not too complex. A classic non-addressable DDI is used for small premises, i.e. small premises with a reduced number of detectors. This brief review has allowed us to identify the elements necessary for the realization of the project.

2.2. Materials

For the realization of the fire detector, we used: A solar energy source; Arduino Uno or microcontroller; Smoke detector; DTH11 detector; LCD screen; SIM800L GSM module. These elements were used to create the block diagram below.

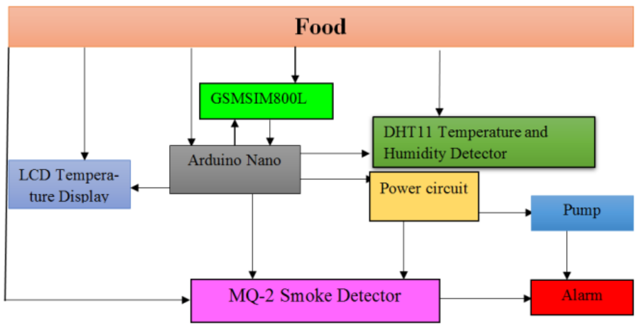


Figure 5. *Plansynopticof the system.*

2.2.1. GSM SIM 800L Module

The GSM module is an electronic device that we have used to monitor, control or manage a number of embedded systems. The principle is the transmission and retrieval of information via the GSM network. It allows to activate or deactivate one or more devices, and to establish a system report. The type of module used here is the SIM800L, which can operate up to a peak current of 2 A [25]. It also has a low power consumption function, requiring only 1 mA in sleep mode. To avoid damaging the module, it is powered from 3.7V to 4.2V. The "SIM800L" is an affordable way to connect to the operator to send SMS via an Arduino Nano board. It has the following characteristics Supply voltage between 4 and 4.8 volts The current supplied by the source must be greater than or equal to 1A.

2.2.2. LCD Screens

Liquid crystal displays, also called LCDs, are compact, transparent, and require few external components to operate. They do not consume power, so their current consumption is between 1 and 5 mA. In our system, the LCD will be configured to display the ambient temperature and humidity of the room.

2.2.3. Arduino Uno

An Arduino board acts as the intelligence, bringing electronic systems to life and animating mechanical devices. It is possible to carry out a variety of projects while maintaining reasonable power consumption using the Arduino Uno. Like other Arduino boards, it shares similarities with its predecessors, while offering unique technical features that set it apart from the rest.

2.2.4. The Pump

To ensure a quick response of the system in case of fire, we selected the SEAFLO brand pump, capable of moving several gallons per hour, the equivalent of three hundred and fifty (350) gallons. This pump is equipped with a powerful twelve-volt motor (12 V, 1.5 A) and has a spacious thermoplastic body. It can also be used to create a water jet or a trickle of water, as well as to water plants. The connection is compatible with pipes with an internal radius of 9.5 mm and has thick cables as conductors.

2.2.5. Smoke Detector

The MQ2 gas isolator is a device capable of detecting gas leaks. It can detect hydrogen, LPG, CH4, CO, alcohol, smoke, propane. It is presented as an electronic component with a metal capsule. It is a metal oxide semiconductor. Gas concentrations are measured using the network voltage divider contained in the sensor. This sensor operates with a low DC voltage of 5 V. It has the ability to detect gases at a concentration whose value is between 200 and 10,000 ppm [25].

2.2.6. DHT1 Sensor

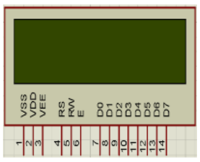
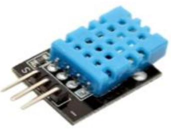
The DHT11 sensor provides temperature and humidity measurements. It is an affordable and accurate sensor that uses an analog-to-digital converter (ADC) to convert analog humidity and temperature values into digital data. The sensor integrates an 8-bit microcontroller for data conversion. It provides reliable results at ambient humidity levels between 20% and 90% with an accuracy of ±5% and a temperature range of 0 ℃ to 50 ℃ with an accuracy of ±2% [25]. These features meet the requirements of most household and general applications.

2.2.7. Alarm

It signals and warns of the presence of a danger in a given area. It transmits information to provoke a reaction [26]. Its intervention is necessary when there is prior knowledge of the danger. In reality, the alarm is triggered as soon as the danger is known. It works spontaneously if the fire detector or the isolator detects the presence of a fire. The operating voltage of the alarm chosen for our project is between 3V and 24V [27].

Table 1. presents a brief characteristic of some elements used for the design of the device.

Table 1. Summary of some components.

Elements	Photos	Roles	Features
Arduino nano		Main system controller.	1. Microcontroller: ATmega328 2. Digital Inputs/Outputs: 14 3. Power supply: USB or 5-12V (DC) 4. 6 Analog Inputs 5. Frequency: 16 MHz 6. Memory: 2 KB SRAM, 32 KB Flash
Alarm		Alert if an anomaly is detected	1. Type: sound or visual (LED) 2. Power supply: 5V-12V 3. Response time: < 1 4. Sound: 85 dB
Pump		Transfers liquids into the system.	1. Type: water pump, air pump, or diagram pump 2. Power supply: 5V-12V 3. Pressure: 0.5-2 4. Flow rate: 100-1000 L/h
LCD screen		Displays information to the user.	1. Type: LCD 16x2 or 20x4 2. Interface: 12C or parallel 3. Brightness: backlit or not 4. Power supply: 5V 5. Consumption: < 0.5W
Smoke detector		Detects the presence of smoke.	1. Type: optical or ionic 2. response time: < 30 seconds 3. Power supply: 5V-12V 4. Sensitivity: 0.1 - 1.0% smoke
Temperature and humidity detector		Measures the ambient temperature. Relative humidity measurement.	1. Type: analog (LM35) or digital (DS18B20) 2. Power supply: 3-5V 3. Type: DHT11 4. Power supply: 3-5V 5. Range: 0- 100% RH 6. Range: -55 ℃ to +125 ℃ (DS18B20

This table summarizes the roles and key characteristics of each component.

2.2.8. Power Supply of the System

The power supply consists of PV solar system to ensure the operation of the device in full time. It is mainly made up of components such as: PV solar panels, the regulator, the accumulator or electric battery, the Inverter as shown in the block diagram below.

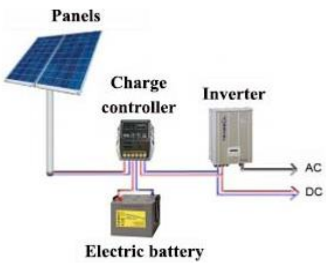


Figure 6. Block diagram of the solar PV system.

Table 2. *Solar System Elements Summary [8].*

Names and Type	Photos	Roles	Typical Characteristics and Values
Solar panels monocrystalline		Converts solar energy into electricity	1. Nominal power 150 Wc 2. Efficiency 15 – 22% per panel 3. Maximum power current 7.10A 4. Short circuit current 8.1A 5. Dimensions1480 x 680 x 35mm 6. Maximum power voltage 22.6 VDC
Battery FREEZE		Stores the energy produced by the panels for later use	1. Capacity 100Ah 2. Voltage Regulation 12V 3. Cycle use 14.5-14.9V 4. Floating use 13.6-13.8V 5. Intensity 30A
SmartSolar MPPT Charge Controllers or Regulators		Manages battery charging and protects it from over-charging and overdis-charging	1. Type Smart Solar MPPT 100/50 2. Voltage 12V/24V 3. Cycle use 14.5-14.9V 4. Floating use 13.6-13.8V 5. Intensity 50 A 6. 95-98% MPPT efficiency
Inverter or converter		Converts direct current to alternating current to operate AC loads	1. Rated power 500W 2 Modified sine type 3. Input voltage 12V DC 4. Output voltage 230V AC 5. Efficiency 85-95%

These elements work together to ensure that solar energy is captured, stored and used efficiently.

3. Results

3.1. Power Supply Circuit

Electronic components are low-power elements. For their energy consumption, it is essential to know the electrical power of each component. Taking into account the standardization and the technical specifications of the designer, we determined the power of each component, as well as the total power of all the electronic elements used. The following equations were applied:

$$P = UI \quad (1)$$

$$P = \sum_{k=1}^{n} U_K I_K \quad (2)$$

In short, the total power is determined by the relationship:

$$Pt = P_P + P_{DT11} + P_{AN} + P_{AL} + P_{BP} + P_{MQ} + P_{GSM} + P_{LCD} \quad (3)$$

3.1.1. Meteorological Data

Meteorological data are essential for the design of the solar system. In this work, for the reliability of the system, we used the irradiation data of Cotonou city. These are presented in Table 3.

Table 3. Irradiation data.

Month	Average daily horizontal radiation per month (kWh/m2/)	Average monthly daily irradiance value over the PV field (KWh/m2/d)
January	5.20	5.87
February	6.09	6.61
March	6.53	6.72
April	6.69	6.51
May	6.70	6.25
June	6.36	5.84
July	6.01	5.58
August	5.64	5.42
September	5.79	5.82
October	5.85	6.21
November	5.46	6.11
December	5.05	5.78

We used the average of the irradiation data of the city of Cotonou for the dimensioning. According to table 3, the average irradiation is EJ = 5.42 kWh/m2/day.

Thus, the peak power PC of the photovoltaic field is determined by:

$$\mathrm{E_{CT}} = \mathrm{E_{AC\ corrigé}} + \mathrm{E_{DC}} \quad (4)$$

3.1.2. Panel Sizing

$$P_C = \frac{\mathrm{E_{CT}}}{K \times E_J} \text{ [28]} \quad (5)$$

The panel number (NP) is:

$$N_P = \frac{P_C}{P_u} \quad (6)$$

3.2. Battery and Regulator Sizing

For optimal use of the batteries we need the battery life. This is at least three (3) days for our project. The total capacity C of the batteries is obtained:

$$C = \frac{\mathrm{E_{CT}}\, N_J}{\boldsymbol{D\ U}} \quad (7)$$

From the total capacity, we can estimate the number of batteries to be wired.

$$Nb = \frac{C}{Cu} \quad (8)$$

Knowing the total regulator current, the number of regulators is:

$$\mathrm{Nreg} = \frac{Ir}{Iu} \quad (9)$$

3.2.1. Inverter Sizing

Let Pt be the total power of the load and Po be the power of the inverter.

$$\mathrm{Po} = 1.5 \times \mathrm{Pt} \quad (10)$$

3.2.2. Sizing of Cable Sections

Cable sizing is important for a photovoltaic installation, as it helps to avoid current losses as much as possible. The sizing and choice of the cable section depend on the following parameters: Length of the conductor L (in meters); Copper resistivity (ρ=1.7.10-8); Maximum short-circuit current at the cable P (ΔUmax=3%); Panel voltage (voltage of the planned wiring). We estimate a length of 3m between the different accessories. The essential formula for determining the cable section in a direct current photovoltaic installation is expressed by the following relationship:

$$S_{min} > 2\, \frac{\rho.L.ISC}{U.P\ (\Delta U\ max)} \quad (11)$$

The different equations that we established allowed us to present the sizing results and the choice of solar components used in our project. To ensure optimal operation and efficiency of the system, we chose energy-efficient devices. These include 12 V and 220 V LED lamps (3 W, 5 W), a 45 W/12 V solder, a 60 W/220 V computer. Table 4. Shows the daily energy in Wh/d for the electronic elements and some loads chosen for the operation of the system. Table 4. presents the energy balance of the system.

Table 4. Energy needs.

Receivers	Quantity	Power ratings (W)	Duration of use (H)	Power ratingsTotal (W)	Consumption/day (Wh)
Formulas	---	B	C	D=AxB	E=DxC
AC receivers					
Television set	1	45	10	45	450

Receivers	Quantity	Power ratings (W)	Duration of use (H)	Power ratingsTotal (W)	Consumption/day (Wh)
Computer	1	60	2	60	120
Lamps	5	5	6	25	150
Pacpower balance (alternative)				130	750
Energy Total Eac wh (alternative)				144.44	833.33
DC receivers					
DC lamps	3	5	6	15	90
DC lamps	2	3	11	6	66
Brewer	1	26	5	26	130
Electronics Component	1	60.67	24	60.67	1456.08
Power balance (continuous)				107.67	
Energy Total (continuous)					1742.08
Total Energy					2575.41
Maximum power					252.11
Installed peak power					730.94

Considering the information in (Table 4) and the sizing equations; we obtained the following results: The total energy consumed per day is 2,575.11 Wh, 150 Wp/12 V in rings; two (2) 100 Ah batteries; the inverter power is 500 W; Charge controller: 50 A; Cables of 6 mm2 and 2.5 mm2 respectively for wiring the panels and other circuit elements. The main electronic components used are listed in Table 5.

Table 5. *List of components.*

No.	Designations	Quantity
01	220 Ohm resistor	25
02	Capacitor	06
03	Temperature display	01
04	Smoke detectors	01
05	Diode	13
06	LED	09
07	Thermistor	01
08	Transistor	02
09	LCD temperature display	01
10	Fan	01
11	GSM Module	01
12	12V pump	01
13	A SIM card	01
14	7812 controller	01
15	NPN transistor	01
16	Arduino Nano	01
17	Programming	01
18	Solar battery	02
19	Load controller	01
20	Converter	01
21	Installation accessories	01
22	Solar panel 150Wc	04

The use of electrical and electronic circuits made it possible to obtain the practical realization of the device as shown in the photos below.

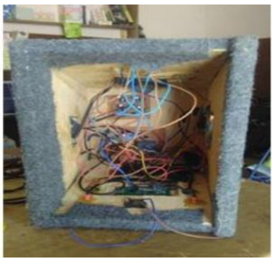


Figure 7. *System Wiring.*

Figure 8. System test completed.

4. Discussion

The implementation of this system represents an innovation in the field of fire and energy safety engineering. The combination of the safety system with a renewable energy source such as a solar photovoltaic system ensures continuous power supply to the system in the event of a power outage on the conventional electricity grid. This solution is ideal because the system can be installed anywhere, even in isolated areas, and the use of renewable energy sources reduces greenhouse gases and helps to preserve the environment. The implementation of this new system represents a real breakthrough in the field of fire and energy safety engineering. By integrating a safety system with a renewable energy source, such as a solar photovoltaic system, this device ensures continuous power supply, even in the event of a power outage on the traditional electricity grid. This solution is particularly suitable for isolated environments, where access to reliable electricity supply may be limited. By using renewable energy sources, we not only reduce our dependence on fossil fuels, but also contribute to the fight against greenhouse gas emissions, thus preserving our environment. Conventional fire safety systems have significant limitations. Many cannot be deployed in non-electrified areas, and those equipped with integrated batteries often face rapid discharge issues. In addition, their need for regular checks raises concerns about their long-term reliability. The new system, although effective, must be redesigned to adapt to modern requirements. It is crucial to equip it with advanced features, such as remote monitoring systems, an intuitive user interface and proactive maintenance solutions. By integrating these innovations, we could offer fire safety that is not only autonomous and environmentally friendly, but also adapted to contemporary challenges.

5. Conclusions and Recommendation

In this study, we have listed the different modes of the security system and the different technologies of the fire safety system. We have listed the different electronic components and their characteristics and presented the different methods of dimensioning the source and electronic elements of the solar system. We have discovered a new approach to fire protection and prevention in warehouses. Tests have been carried out to evaluate the operation of the system. The integration of solar energy in fire safety systems is not only a trend but an imperative. It is time to adopt these innovations to create an environment where safety and sustainability go hand in hand. By investing in these technologies, we are making an informed choice for our safety and that of our planet. This path towards modern and autonomous fire safety is not only feasible but also necessary for a sustainable future. Solar energy, as a power source for fire safety systems, offers a multitude of benefits that are worth exploring and developing. Adopting this approach is a step towards a more resilient and responsible society, capable of facing the challenges of tomorrow.

Abbreviations

A	Ampere
AC	Alternating Current
CE	Daily Energy Consumption
CH4	Methane, a Hydrocarbon
CO	Carbon Monoxide
Cu	Capacity of a Battery
DC	Direct Current
D	Degree of Discharge
DDI	Device Data Interface
DHT	Humidity and Temperature Sensor
LED	Light Emitting Diode
LCD	Liquid Crystal Display
L/h	Liters Per Hour
MPPT	Maximum Power Point Tracker
Nb	Number of Batteries to Use
Nreg	Number of Regulators
Iu	Regulator Current
Smin	Minimum Cable Section
U	System Voltage
V	Volt
W	Watt
Wc	Peak Watt
LPG	Liquefied Petroleum Gas

Author Contributions

Moussa Ibrahim: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Writing – original draft

Agbokpanzo Richard Gilles: Formal Analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – review & editing

Irénée Vianou Madogni: Validation, Visualization, Writing – review & editing

Agbomahena Macaire: Validation, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Zhang, Y., Li, H., Zhang, Y., Li, H., and Wang, J. (2020). Residential Fire Incidents: An Analysis of Trends and Pattens Wang, J. (2020). Fire Technology, 56(2), 345-360. https://doi.org/10.1002/celc.202000650

[2] Mr. Taylor, J. Fielding, al (2024) Bayesian analysis of home fire response and fire injuries, Volume 150, Part A, December 2024, 104266 https://doi.org/10.1016/j.firesaf.2024.104266

[3] CHETTOUH SAMIA, STATISTICAL MODELS FOR THE EVALUATION OF UNCERTAINTIES ASSOCIATED WITH THE EFFECTS OF FIRE RISK. Doctorate thesis, (2016) University of Batna http://dspace.univ-batna2.dz/handle/123456789/382.hyg Samia Chettouh.pdf(7.96 MB)

[4] W. Tannous, M. Whybro, al 2018 Home fire safety checks in New South Wales: an economic evaluation of the pilot programJ. Risk Res., 21(8) (2018), pp. 1052-1067 https://doi.org/10.1080/13669877.2017.1281336

[5] International Fire Safety Standards. (2021). Best Practices in Fire Prevention. Global Fire Safety Journal.

[6] Friedman, A., Green, L., & Thomas, R. (2020). Fire Safety Management: Challenges and Innovations. Journal of Safety Research, 45(3), 123-135.

[7] Hary AgusRahardjo The most critical issues and challenges of fire safety for building sustainability in JakartaVolume 29, May 2020, 101133 https://doi.org/10.1016/j.jobe.2019.101133

[8] Smith, J., & Jones, M. (2021). Renewable Energy in Fire Safety Systems: A Review. International Journal of Environmental Science, 56(2), 78-92.

[9] Qusay; al Hassan (2023) A review of hybrid renewable energy systems: Solar and wind-powered solutions: Challenges, opportunities, and policy implications; Volume 20, December 2023, 101621 https://doi.org/10.1016/j.rineng.2023.101621

[10] Sangmin Park, Sanghoon , al 2023 Smart Fire Safety Management System (SFSMS) Connected with Energy Management for Sustainable Service in Smart Building Infrastructures *Builings* 2023, *13*(12), 3018; https://doi.org/10.3390/buildings13123018

[11] Nguyen, T, Brown, K, and White, L. (2022). Solar Energy Solutions for Remote Fire Safety Renewable Energy Research, (4), 201-215

[12] United Nations. (2023). The Role of Renewable Energy in Achieving Sustainable Development Goals. UN Publications.

[13] Patel, R., Lee, S., & Martin, E. (2021). Hybrid Energy Systems for Disaster Resilience: A Case Study. Journal of Energy and Development, 47(1), 10-23.

[14] Johnson, P., White, R., & Adams, T. (2022). Innovations in Smoke Detection Technology. Journal of Fire Safety Science, 45(1), 90-102.

[15] Kumar, S., & Singh, A. (2021). Design and Implementation of Fire Alarm Systems. Journal of Electrical Engineering and Technology, 16(3), 1135-1144.

[16] Hary Agus Rahardjo, Morry Prihanton The most critical issues and challenges of fire safety for building sustainability in Jakarta, Volume 29, May 2020, 101133 https://doi.org/10.1016/j.jobe.2019.101133

[17] Chen, M., Wang, Y., & Xu, Q. (2023). Testing Methods for Fire Detection Systems: A Comprehensive Review. Safety Science, 144, 105-119. Fire 2023, 6(8), 315 https://doi.org/10.3390/fire6080315

[18] NF S 61-933: Fire safety systems – Requirements for fire alarms., consulted on August 20, 2024 at 10 p.m.

[19] NF EN 54: Fire detection and alarm systems, consulted on August 22, 2024 at 11:20 a.m.

[20] NF S 61-971: Fire-fighting equipment., consulted on September 10, 2024 at 3:20 p.m.

[21] Order of June 25, 1980: Safety standards for establishments receiving the public., consulted on September 15, 2024 at 3:20 p.m.

[22] Eshrag Ali , Abdullah , al 2024 A-Deep-Learning-Based-Approch to the Classification of Fire Types *Appl.Sci.* 2024, *14*(17), 7862; https://doi.org/10.3390/app14177862

[23] Fire Detection System (FDS) - Recherche Images, consulted on September 15, 2024 at 3 :20 p.m. https://www.bing.com/images/

[24] Fire Safety: Automatic vs. Manual Fire Alarm Systems | Securitas Technology20, 2024 at 10 a.m. https://www.bing.com/images/Securitastechnology.com/uk/blog/

[25] Kaouthar Draif (2023) Utilization of Sim800L GSM moule with Arduino; https://letmeknow.fr/fr/blog/94-tuto-module-gsm-sim800l---prise-en-main consulted on September 20, 2024 at 4:20 p.m.

[26] EngeninYitong Feng, Fuli Xu, Fei-Fei Chen, Yan Yu Smart fire alarm systems for rapid early fire warning: Advances and challenges https://doi.org/10.1016/j.cej.2022.137927

[27] Functional analysis of a fire alarm CETSIS 2010, Grenoble, March 8-10, 2010; 09 pages.

[28] International Journal of Innovation and Applied Studies ISSN 2028-9324 Vol. 38 No. 4 Feb. 2023, pp. 847-859 © 2023 Innovative Space of Scientific Research Journals Corresponding Author: Abdou Hamidou 847 Method of dimensioning a photovoltaic system as a backup source of power for a computer laboratory: the case of the computer laboratory at ISTA Lukula, Boma, DR Congo. http://www.ijias.issr-journals.org/