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Innovation in Smart Fencing with Internet of Things (IoT) Technology for Ease of Use

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Abstract

The fence is a structure that is deliberately designed to limit or protect the house. The fence serves to provide protection or block views so that the house becomes safer. It is usually pushed manually by hand to open and close the fence. This is considered very inconvenient and time-consuming. This problem underlies the idea of creating an automatic fence opening and closing system using a smartphone by utilizing Internet of Things (IoT) technology in order to facilitate human work to open and close the fence. A smartphone is used as a NodeMCU controller contained in the ESP8266 WiFi module via an internet connection to connect to the Android Studio application. To move the fence using an electric motor as the driving force which is connected directly to NodeMCU. When the fence opens and closes, the relay will regulate and activate to give orders to the electric motor to move the fence. The fence will stop when the switch opens and the switch close responds, the motor will stop moving. Realtime data results are stored in Firebase and the results of this design are expected that all components are connected properly so that automatic fences can be used.

Keywords: *fence, Internet of Things (IoT), electric motor, NodeMCU*

Abstrak

Pagar merupakan struktur yang sengaja dirancang untuk membatasi maupun melindungi rumah. Pagar berfungsi untuk memberikan perlindungan maupun menghalangi pandangan agar rumah menjadi lebih aman. Untuk membuka dan menutup pagar biasanya mendorong secara manual menggunakan tangan, hal tersebut dirasa sangat merepotkan dan menyita waktu. Permasalahan ini yang mendasari adanya ide untuk membuat sistem pembuka dan penutup pagar secara otomatis menggunakan smartphone dengan memanfaatkan teknologi Internet of Things (IoT) supaya memudahkan pekerjaan manusia untuk membuka dan menutup pagar. Smartphone berguna sebagai pengontrol NodeMCU yang terdapat pada modul WiFi ESP8266 melalui koneksi internet agar terhubung ke aplikasi Android Studio. Untuk menggerakkan pagar menggunakan motor elektrik sebagai penggeraknya yang terkoneksi langsung dengan NodeMCU. Pada saat pagar akan membuka dan menutup maka relay akan mengatur dan mengaktifkan untuk memberi perintah kepada motor elektrik untuk menggerakkan pagar. Pagar akan berhenti apabila switch open dan switch close merespon maka motor akan berhenti bergerak. Hasil data secara realtime tersimpan di Firebase dan hasil perancangan ini diharapkan semua komponen terhubung dengan baik sehingga pagar otomatis dapat digunakan. Inovasi ini diharapkan memberikan kontribusi berharga bagi perkembangan ilmu pengetahuan serta meningkatkan kualitas hidup masyarakat melalui pemanfaatan teknologi canggih yang merespon kebutuhan akses pagar dengan lebih intuitif dan efisien.

Kata Kunci: *pagar, Internet of Things (IoT), motor elektrik, NodeMCU*

1. INTRODUCTION

The fence is the main part of a house in terms of security. The fence is an element part of the design of a house that is important for its existence [1]. The fence has a function as a barrier or safety designed to limit or prevent movement across the boundary it makes [2]. Fences are usually made of an access point by opening the door by pushing it to the right or left [3]. The fence used is a sliding fence that moves and runs on rails with wheels mounted on the bottom of the fence. To open and close the fence must be done by moving the door by hand, moreover, if a vehicle such as a car wants to go out and enter the house you have to get off the vehicle first, and if during certain conditions such as rain opening and closing the gate of the house, it will be very troublesome and time-consuming. This problem underlies the idea of making fences open and close automatically using a remote and smartphone (android) by utilizing Internet of Things (IoT) technology. Where the system used contains an arrangement of infrastructure that is integrated with each other so that it can make human work more effective and efficient, the Internet of Things (IoT) runs by utilizing the use of smart devices and internet networks.

The Internet of Things (IoT) is a network of physical objects. The internet is not just a network of computers but has developed into a network of devices of all types and sizes, vehicles, smartphones, household appliances, toys, cameras, medical equipment, industrial systems, animals, people, buildings, everything connected, everything communicating and information sharing based on established protocols to achieve intelligent reorganization, positioning, browsing, security, control, and even personal real-time online monitoring, online upgrade, process control, and administration [4]. The importance of the Internet of Things can be seen by its increasing application in various lines of life today. IoT gives us many ideas to participate in various aspects of development from micro to macro around the world [5]. IoT must be able to provide information about environmental conditions and control electronic devices in real time, therefore using Firebase as a database capable of sending data in real time [6].

In an increasingly connected world and as technology evolves, gates are becoming more than just physical boundaries that separate spaces [7]. The need for secure, fast and convenient access is increasing, driving innovations in the form of smart fence innovations with IoT technology for user convenience. The sophistication of Internet of Things (IoT) technology offers an exciting and effective way to address these challenges. The combination of connected hardware and intelligent software allows the fence to interact with its environment and respond to user needs in real-time. This means that users can control their gate with ease, whether they are nearby or not.

By addressing existing problems, this research also brings a new concept to the world of fence access, providing a more practical, faster and safer solution. By applying this technology, the innovation relies on technical sophistication. It ensures that the user experience remains easy to access, even for those with a deep technical background. The results of this research not only reflect a new technological solution but set our sights on a more connected future. This innovation contributes not only to our understanding of how technology can play an important role in providing real solutions but also to our understanding of how technology can be used to improve our lives.

Based on researchers' research of automatic gate systems [8], this system uses RF 315 wireless remote control. This system has a weakness, namely the use of remote control is very limited. If the homeowner leaves the remote control behind, the homeowner cannot enter the house. Researchers [9] researched automatic garage door control systems. This system uses RFID indicators. The weakness of this system is that the RFID tag is unreadable or has an error, so the garage door cannot be opened. Meanwhile, based on research [10] on an automatic gate control system using digital image processing of vehicle license plates. This control system also has drawbacks, namely the

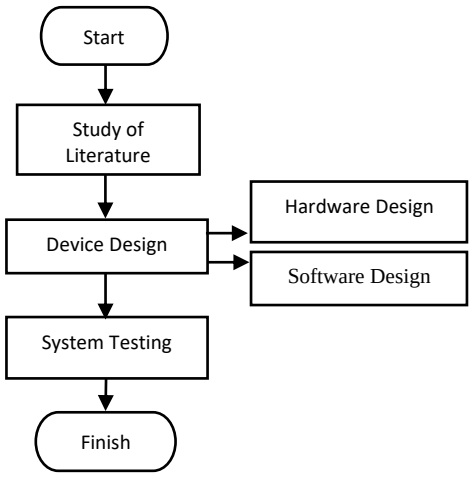
vehicle license plate detection sensor can only be used with a maximum distance of 20 cm.

The Smart Fence Innovation with IoT Technology for User Convenience presents several novelties and advantages that distinguish it from other research in this field is an innovation designed with a focus on user convenience, the use of Internet of Things (IoT) technology, which shows that the fence is not just a static tool, but is actively connected to the surrounding environment and can respond to various situations, the ease of remote access which allows users to control the fence remotely via smartphone which provides advantages in terms of convenience. In the era of ever-evolving technology, innovation continues to be the main driver to meet society's demands for convenience and efficiency. In this context, this research aims to realize a significant step forward by developing "Smart Fence Innovation with IoT Technology for User Convenience". By combining revolutionary Internet of Things (IoT) technologies with the need for easy access, this research presents a solution that stands out by providing a more intuitive and responsive door access experience. In this introduction, we will explore the novelty and key benefits of this innovation and illustrate how this research significantly contributes to the development of science and the welfare of society through the use of advanced technology.

Based on these studies, the authors designed an automatic fence control system based on the Internet of Things (IoT) with the aim of facilitating human work in opening and closing fences and protecting homeowners to remain safe when opening and looking at the fence at night or when bad weather. This study aims to design automatic fences using IoT technology by answering the research question of whether automatic fences can be designed based on IoT. The research analysis is that fences can be designed and used using IoT technology installed on smartphones. This system uses NodeMCU as the controller for the gate. NodeMCU Esp8266, is an IoT device or wifi module that can be integrated with devices to be controlled and monitored via the internet network [11]-[12]. An electric motor as the drive for the gate, and an Android smartphone as a device that orders the fence to open or close directly connected to the internet. All devices are connected using the internet with the Android Studio application.

2. RESEARCH METHOD

The following section presents the architecture of the Internet of Things (IoT) Based Automatic Fence Control research. How to design the entire system can be seen in the image below.

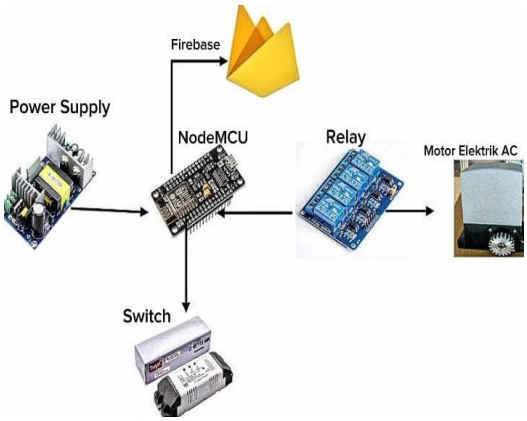


Picture 1. Research Architecture Diagram of Automatic Fence Control System

Picture 1 is the overall flowchart of the research methodology step framework for Internet of Things (IoT) Based Automatic Fence Design. In this research, a literature study was carried out by collecting and taking references from various sources such as books, theses, journals, and the internet, where these sources will become a reference for this research.

Hardware design is the process of designing all components until they are all connected to the fence. The hardware design starts with creating a schematic. The NodeMCU, which uses the ESP8266 WiFi module, is connected to a 24-volt power supply as the power source. The 4-channel relay module helps control the opening and closing of the fence when it receives commands from the NodeMCU. The relay will activate when it receives a command, so the motor driver will rotate and move the fence to open and close. The electric motor used is an AC-type electric motor because this type of motor is stronger to move the large weight of

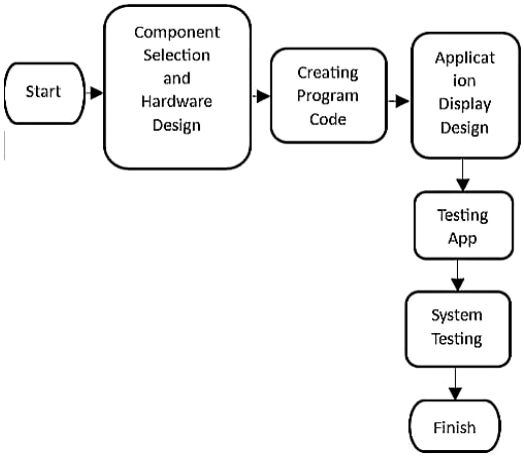
the fence. The motor driver will stop moving when the open switch and close switch respond, where the switch functions to disconnect the movement of the motor wheel, then the motor driver will stop, and the fence will automatically be stationary. The hardware design can be seen in the picture below in Picture 2.



Picture 2. Hardware Design

Table 1. Hardware Component Specifications

No	Component Name	Description
1	Motor Electric AC	a. Power AC b. Motor Speed 1400 Rpm c. Max Gate Weight 1000kg d. Gate Speed 12m/min e. Temperature -20°C - 55°C f. Protecting Class IP44
2	NodeMCU	NodeMCU ESP8266
3	Power Supply	Power Supply 24V
4	Relay	Modul Relay 4channel
5	Switch	Switch Open & Close



Picture 3. Automatice Fence Control Software Design

Picture 3 is a framework that will be executed in software design that aims to produce a fence control application design. The stages include:

a. Component selection and hardware design

The first step is to select the components that will be used for the hardware design. These components include a 24V power supply, NodeMCU ESP8266, 4-channel relay module, AC electric motor, open switch, and close switch.

a. Application display design

The application display design aims to make the application display design easier to make. In designing the application is designed using Android Studio.

b. Create program code

The hardware program code is created on the Arduino IDE using the C++ programming language, and the application program code is created in Android Studio using C++ and Java. The hardware program code is connected through Firebase as a data processor, and the data is sent to NodeMCU. NodeMCU reads the sent data and gives incoming commands at the same time.

c. Test the appearance of the application

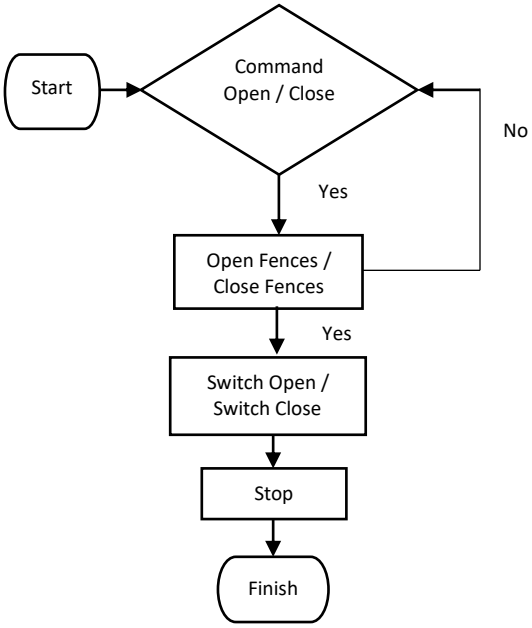
Testing the application display is to test each option that is available with the features that have been designed then, the application is successful if all the features that have been designed are used successfully.

d. System testing

This section includes system testing related to tools and applications that have been designed and successfully tested.

System testing in this design includes application testing, which aims to see if application commands can operate the fence. Testing the electric motor wheel movement function to see if it works as expected. Distance and network speed testing aim to see how the fence speeds up at different distances and network speeds. Finally, see the results of power consumption used in testing the system. System testing first made a flowchart to describe the program's course against the system. The picture below is a flowchart process in testing the system to be made. The first step is to start and initialize any tools or components used. If the fence is open, the motor will move until the open switch command responds (yes), and the motor will stop automatically. The motor will move if the fence is closed until the Close switch command

(yes) responds. Then, the motor will stop, and the fence will close. If the open or closed switch does not respond, the fence open/close command is repeated. The flowchart is shown in Picture 4.



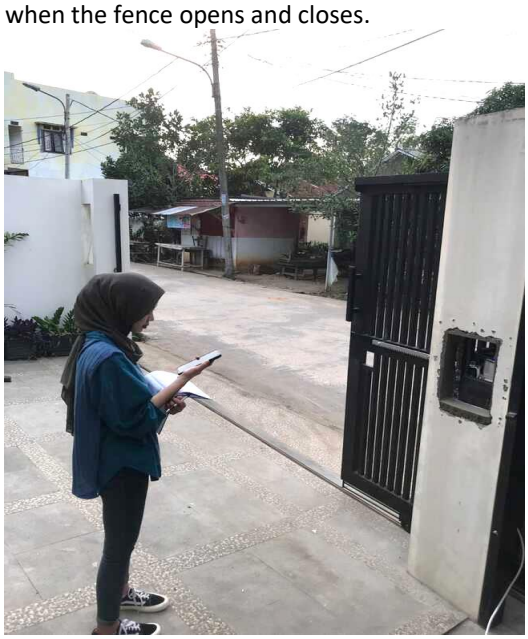
Picture 4. Complete System Experiment Flowchart

In this test, the component will be placed near the fence, where it will be tested in its entirety by the automatic fence opening and closing test. Then several variables were measured which included voltage, current, electric motor speed, and the electric power used. As well as the rotation and time needed by the fence when opening and closing. Test data will be stored in real-time in Firebase using the Arduino Caesar Chiper method (random writing method) which is confidential so that incoming data is not known to other people.

3. RESULT AND DISCUSSION

3.1 Data Description

The results of this research are based on components assembled and programmed based on the Internet of Things (IoT) using smartphones with applications made with Android Studio. In this design, using a type of iron fence sliding, this fence weighs about 500 kg with a length of 5.25 meters. This tool was designed as a set of components consisting of a 24-volt power supply as a power source for the device, NodeMCU as a component that is connected by the application using the ESP8266 wifi module and instructs the device. Nodemcu is connected to Firebase to execute commands in the application. The relay is turned on when it receives a command to move the electric motor. The type of relay used is a 4-channel relay module. The electric motor used is an AC motor that can move the fence with a maximum weight of 1000 kg at a motor speed of 1400 rpm. AC electric motors are used because the fence to be installed weighs approximately 500 kg, so it is safe and avoids overloading the motor. When the motor is moving, the switch performs its function to disconnect or stop the movement of the motor wheel when the fence is in motion. Picture 5 and Picture 6 below are the research results when the fence opens and closes.



Picture 5. Fence in Open State

Picture 6. Fence in Close State

3.2 Discussion

A. Hardware Program Code Section

The program code section in Picture 7 is a hardware interface program that uses the Arduino IDE.

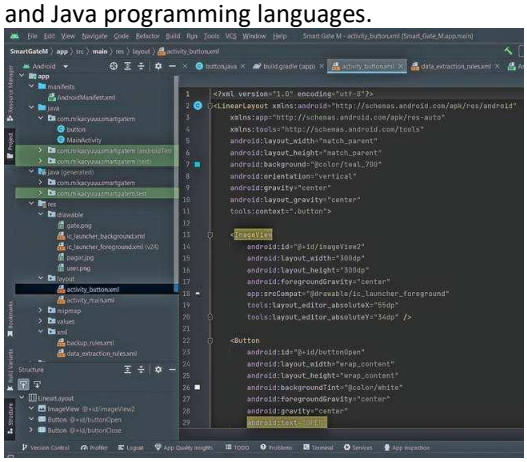
```
#include <Arduino.h>
#if defined(ESP32) || defined(ARDUINO_RASPBERRY_PI_PICO_W)
#include <WiFi.h>
#elif defined(ESP8266)
#include <ESP8266WiFi.h>
#endif

#include <Firebase_ESP_Client.h>

// Provide the token generation process info.
#include <addons/TokenHelper.h>

// Provide the RTDB payload printing info and other helper functions.
#include <addons/RTDBHelper.h>

/* 1. Define the WiFi credentials */
#define WIFI_SSID "WIFI_AP"
#define WIFI_PASSWORD "WIFI_PASSWORD"

// For the following credentials, see examples/Authentications/SignInAsUser/EmailPassword/EmailPassword.ino

/* 2. Define the API Key */
#define API_KEY "API_KEY"

/* 3. Define the RTDB URL */
#define DATABASE_URL "URL" //<databaseName>.firebaseio.com or <databaseName>.<region>.firebasedatabase.app
```

Picture 7. Hardware Program Code on Arduino IDE

In Picture 7 NodeMCU is programmed in C++ using WiFi and a WiFi Password to connect to the internet. The data files will be managed using Firebase which is programmed on the Arduino IDE, then the data will be entered in real-time.

B. Application Programming Code in Android Studio

This section is a program component created to design the appearance of the application to make it easier to control the tool to be tested. The application display page is designed in Android Studio with a view menu whose features have their respective functions. The application display program code uses the C++ and Java programming languages.



Picture 8. Software Design Program Code in Android Studio

In Picture 8 several program codes are entered for the application display design in the form of open menus and closed menus. <LinearLayout which is for creating a layout for the element to be used. <ImageView is the program code when adding image elements to the application view you created. <Button is the program code on a pushable element or button element.

C. Application Display Page Results

In this section are the results of the design program for making automatic fence control applications. The design is made with a menu page that can be used for fence controllers to open and close, data obtained in real-time will be entered in Firebase. Applications that have been designed will be transferred to smartphones that are directly connected to the internet network. The display menu on the application installed on the smartphone can be used based on the features and functions that have been made. Smartphone (android) must be connected to the internet when running the system. The commands on the fence cannot be executed if the application is not connected to the internet. Suppose the internet is experiencing bad signal interference due to weather. In that case, the possibility is to wait for the internet to reconnect or the state of the internet in a stable connection. The picture below is the result of displaying the designed application. The difference between the two is the location of the application designed in Android Studio, and then its use is moved into the smartphone as a controller. Both have the same menu because the results of displaying the application on the smartphone are the results of designing in Android Studio, which is then moved into the smartphone.

Picture 9. Application Menu in Android Studio

Picture 10. Application Menu on Smartphone

Picture 9 is the display result in Android Studio with image elements and buttons that have been designed with programs in Android Studio. Picture 10 is the display result of the application on a smartphone which has been tested for each feature based on its function before being used on the fence. The results of testing the application function can be seen in Table 2 below.

Table 2. Application Testing Results

Command	Required Time (Second)	Results Description
Open	23,74	Succeed
Close	23,67	Succeed
Stop	0	Succeed

Based on Table 2 the results of application testing were successful with different time descriptions. To open, moving the fence takes 23.74 seconds until the fence stops moving. Meanwhile, to close, moving the fence requires less time than opening it, which is 23.67 seconds. The fence immediately stops moving and stays still for 0 seconds. The fence immediately stops moving and stays still for 0 seconds. The test of the application function is successfully executed on each command, which then when you want to control the fence, use the application installed on a smartphone (Android) using an Internet connection. At the time of testing, the Internet connection system did not experience any interference or was stable, so the test was performed as intended. If the Internet conditions are interrupted or not connected, what happens is that you have to wait for the Internet to reconnect to give commands to run the fence control.

D. System Testing Results

In this section, data is the result of testing the Internet of Things (IoT) Based Automatic Fence Control System, where the system being tested is the performance of the tool that has been designed, the results of the fence control distance test using a smartphone connected to an internet connection, as well as the results of electricity consumption used on when testing the system. Incoming data will be sent to Firebase with the letter randomization method.

Table 3. Electric Motor Test Result

Wheel Movement	Wheel Spin	Result Description
Onward	Spin Forward	Corresponding
Back Off	Spinning Back	Corresponding
Stop	Not Moving	Corresponding

Table 3 is the result of the electric motor drive function test. Based on Table 3 the movement of the electric motor is successful according to its function, where when the wheel is forward the wheel rotates forward, while when the wheel is backward the wheel rotates backward, when the wheel stops moving the wheel will stop and stop moving.

Table 4. Test Fence Controller Distance with Network Speed

Range	Network Speed	Fence Speed	Description
1 Meter	2,00 Kbps	Normal	Succeed
2 Meter	0,30 Kbps	Normal	Succeed
3 Meter	0,26 Kbps	Normal	Succeed

Table 4 shows that the fence control distance test was successfully performed at different network speeds. The relationship between distance and kbps (kilobits per second) can affect system performance and responsiveness when testing automated Internet-connected fences. While physical distance may not have a direct impact on kbps speed, there are ways in which distance can interact with Internet connection performance in this context, namely signal quality. Whereas the distance between the device and the wireless access point increases, the wireless signal quality may decrease. Poor signal quality can result in a decrease in kbps speed and even dropouts. The Auto-Fence system response may also be affected if the connection becomes unstable. The speed of the gate has no effect at short or long distances. Network speed in a fast or slow signal state does not cause the gate speed to change. The network speed is very low because the application does not consume much Internet network. To see the network speed, it was recorded on the smartphone (Android) used to test the system.

Table 5. Result of Electricity Consumption

Fence Condition	Voltage (Volt)	Current (Ampere)	Power (Watt)
Normal	211	0	0
Open	211	3,4	717,4
Open 1/2	211	3,0	633
Open 1/4	211	3,3	696,3
Close	211	7,8	1645,8
Close 1/2	211	7,8	1645,8
Close 1/4	211	7,4	1561,4

Table 5 shows the power consumption used during the system test. The source voltage is 211 volts, measured with a multimeter, and the current output differs. The current used to open the fence is lower than the current used to close the fence, in this case, because the movement of the fence is heavier when the command is to close than when it is to open. The power consumption ranges from 633 to 1645 watts depending on the output current and voltage of the source. Power calculation is based on the principle of Ohm's law [13], where the formula is as follows:

$$P = V \times I \quad (1)$$

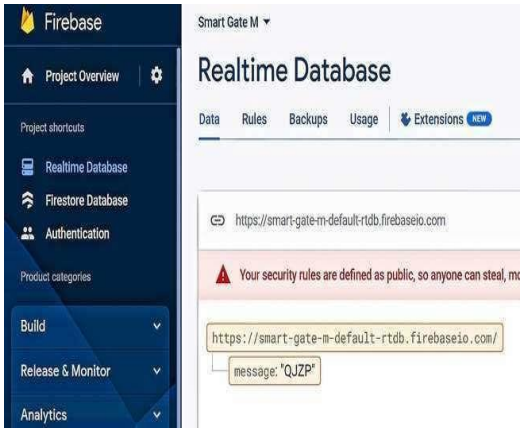
Description: P = Power (watt)
V = Voltage (volt)
I = Current (ampere)

The voltage results do not change, and the current results change because the electric motor used in this design is an AC-type electric motor. AC type electric motor is an electric motor that is driven by alternating current or alternating current (AC), where AC voltage is a voltage whose result is the same as the current, which is always changing and alternating [14].

Incoming data will be immediately sent to Firebase in real time. For data security, use the Arduino caesar chiper method (random letter method) so that if the incoming data is unknown or confidential. The results of the data sent can be seen in Picture 11 and Picture 12.

Picture 11. Data Result “Open”

Picture 11 is the result of the data when the fence moves open with the message: "IJIJE". Commands are entered through the application by pressing the open button then the motor moves the fence and real-time data results are sent to Firebase.



Picture 12. Data Result “Close”

Picture 12 is the result of the data when the fence moves closed with a message: "QJZP". Commands are entered through the application by pressing the close Button then an electric motor moves the fence and real-time data results are sent to firebase.

4. CONCLUSION

In this design, it has successfully developed an automatic fence control system using Internet of Things (IoT) technology, with the advantage of being able to open the fence via a smartphone (android), which can be controlled remotely without having to push with your hands and walk towards the fence manually. Based on the results of the design and testing of an Internet of Things (IoT)-based automatic fence control system, it can be concluded that various components can be used properly and work according to their functions. The results of the data tested as a whole are appropriate and successful. The movement of the fence either opens, closes, or stops according to the expected test. The electric motor moves the fence, the wheels rotate forward when the wheel moves forward, the wheels rotate backward when the wheel moves backward, and the wheels will automatically stop when the electric motor moves stop. By using the application, opening and closing the automatic gate can be set using an application installed on a smartphone that is connected to an internet connection. Applications that are designed according to and successfully tested each feature that is in the application display. Testing the distance of the controller with an internet connection does not change the movement of the fence. Move the fence running normally from a distance of 1 meter or 3 meters. System testing uses electric power consumption ranging from 633-1645 watts. With a source voltage of 211 volts and an opening current of 3.0-3.4 amperes, and a closing current of 7.4-7.8 amperes. We hope that the results of our research can be useful as well as learning. In future research, it is expected to be able to develop an Internet of Things (IoT)-based automatic fence control system that can be developed with a variety of other methods and is useful according to its function.

STATEMENT OF APPRECIATION

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