Implementation of Lead Acid Usage with Resistive and Inductive Testing Using Fuzzy Logic Method IoT Monitoring System

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Abstract. The lead-acid battery is one type of rechargeable battery that is widely used by the public. Lead-acid batteries have many advantages, including lead-acid batteries that are easy to find and relatively inexpensive. However, the problem that is often faced by lead-acid battery users is that the user does not know the condition of the battery whether the battery is in a condition that must be charged or not. this needs to be known so that the battery used is not easily damaged. One way that users can find out the condition of the battery is to use a tool consisting of a power sensor and a temperature sensor to detect the condition of the battery as well as displays such as HMI monitors and web servers so that the data read by the sensors can be seen directly by battery users in real-time. . This study used the waterfall method so that the results showed that the battery voltage during the charging process increased according to the characteristics of the battery used and the battery voltage when the battery was loaded decreased according to the characteristics of the battery used. And the data read by the sensors used in this study can be displayed through the HMI and web server in real-time..

Keywords: Lead Acid Battery, Power Sensor, Temperature Sensor, HMI Monitor, Web Server.

1 Introduction

Electrical energy sources are the most widely used sources by humans today. This is because electricity is a very vital need in human life. The need for electrical energy sources is increasing and this increase must be balanced by the supply of these electrical energy sources. One alternative source of electrical energy supply is a battery. Battery at this time has become a very important part of everyday life. Especially in batteries, the battery has the function to supply electrical energy to the starter system, ignition system, lights, and other electrical components. [1][2][3][4][5]

A battery or accumulator is an electric cell in which a reversible electrochemical process takes place with high efficiency. What is meant by a reversible electrochemical reaction is that in the battery there can be a chemical conversion process into electric power (discharging process) and vice versa from electric power into chemical energy (charging process) using a regeneration process from the electrodes used, namely, by-passing an electric current. in the direction of the opposite polarity inside the cell.

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Batteries generate electricity through chemical processes field[6][7] [8][1]. In electronic equipment, especially on motors and batteries, an automatic monitoring system is needed because with this system the entire energy use of the driving motor can be known field[9][10]. The battery used as an energy storage medium in the electrical system is a secondary battery type, namely a battery that can be recharged by an electric charge (rechargeable)[11][12][13][8]. In addition, the battery used must be of the deep cycle battery type, which is a battery that can be discharged with a large enough percentage of its maximum capacity. Until now, the most widely used battery in electrical systems is the lead-acid battery because the price is quite cheap, and the safety level is quite high. The lead-acid battery is an important component and has been used in everyday life[1], [4], [11], [14]–[20]. This battery is used as a starter battery in cars, buses, forklifts, and other modes of transportation. Lead-acid batteries are also the main supply for major emergency electrical system needs to maintain and ensure critical components can still work and no data is lost in the event of a power outage. In the process of charging (charging) and discharging (discharging) it is necessary to pay attention to the value of the voltage and current of the charging and discharging process, so that there is no excessive charging or discharging (overcharge and overtrain). This is done so that the battery life becomes longer and the energy stored is more optimal. Car/motorcycle batteries are designed for SLI (Starting Light Ignition) use, this means that the battery voltage must be high. In other words, if the electrical energy in the car/motorcycle battery is drained to 50% or more of its total capacity, the battery will be damaged quickly. Prevention that needs to be done is to check regularly and refill the battery optimally. Charging the battery can be done optimally when the engine rotation is optimal or proportional to the power that has been issued by the battery to carry out electrical functions. The problem that arises is that motorized vehicle users do not know the condition of the battery which has reached a voltage level below the average of 85%[21][9], [22][9], [23], [24]. If there is a problem with the regulator, then the charging current in the battery becomes excessive. The voltage value produced by fast charging is good and normal at a voltage level of 13.4V– 14.8V. The battery capacity is expressed in Ah units if the battery has a voltage of 12V and a current of 3A, theoretically, the battery can provide a current of 3A/hour, which means that it provides an average power of 36 W/hour. In addition to fast charging and the temperature of the battery body, the problem that occurs in the battery is that the battery cannot store electric current, when the vehicle is used for long trips by turning on the maximum load, the load runs smoothly which means fast charging works well but the battery cannot store electric current over a long period. It is necessary to monitor current (I), voltage (V), power (P), and the temperature (T) that comes out when the engine is turned on or not working. From this background, the author designed a device that can monitor the conditions of current (I), voltage (V), power (P), and temperature (T) on fast charging for batteries and on batteries for resistive and inductive loading in which all information These are displayed on the HMI monitor screen which can be placed on the panel of an instrument and can also be displayed on the website. So that instrument users will be able to know the condition of the battery directly on the monitoring panel and smartphones or laptops.

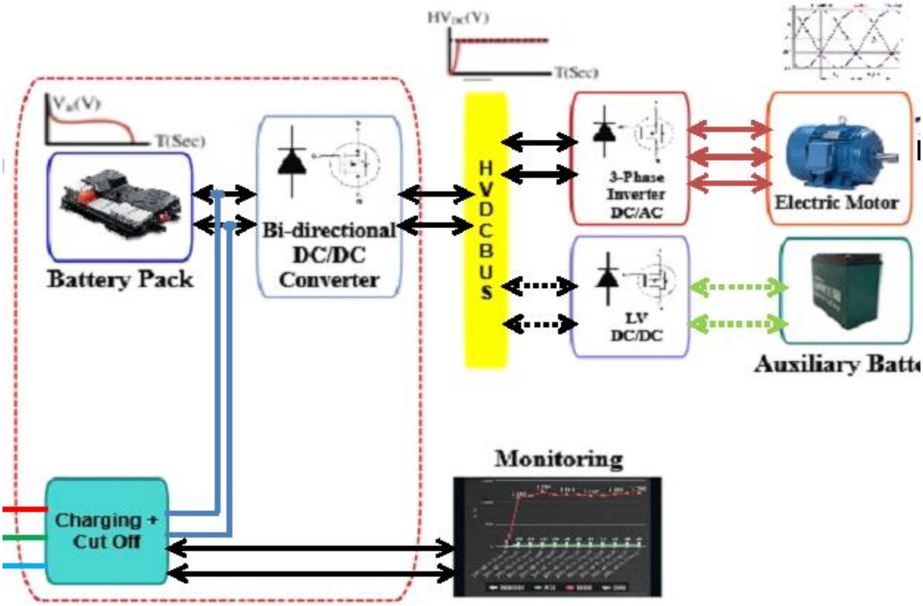


Fig. 1. Wiring diagram Battery Circuit

1.1 Basic Theory Lead Acid Battery

A lead-acid battery has the properties of a secondary battery (rechargeable battery)[25][26][27]–[29]. A fully charged lead-acid battery has an acid density of about 1.24 kg/liter at 25°C. The acid density will vary according to the temperature and charge state of the battery. The nominal voltage of each lead-acid cell is about 2 Volts. The voltage in the open circuit is a direct function of the electrolyte concentration ranging from 2.125 V for a cell with a specific gravity of 1.28 and an electrolyte to 2.05 V for specific gravity of 1.21. The cut-off voltage during the discharge process ranges from 1.75V per cell but can reach 1V per cell at very high discharge rates at low temperatures. Lead-acid batteries will self-discharge between 1% and 5% per month at 200˚C. This release reaction involves the decomposition of water to form hydrogen and oxygen. The self-discharge rate will increase with increasing temperature. If the process continues without charging[30]. The following characteristics of lead-acid batteries are The lead-acid battery consists of several main components, as shown in the snippet in Figure 2. This figure shows the construction of an automotive IDD battery. The application of the various cells and batteries determines the design, size, quantity, and type of material used. The active components of a lead-acid battery are usually less than half of their total weight. The main starting material is highly purified lead[30][31][6][8]..

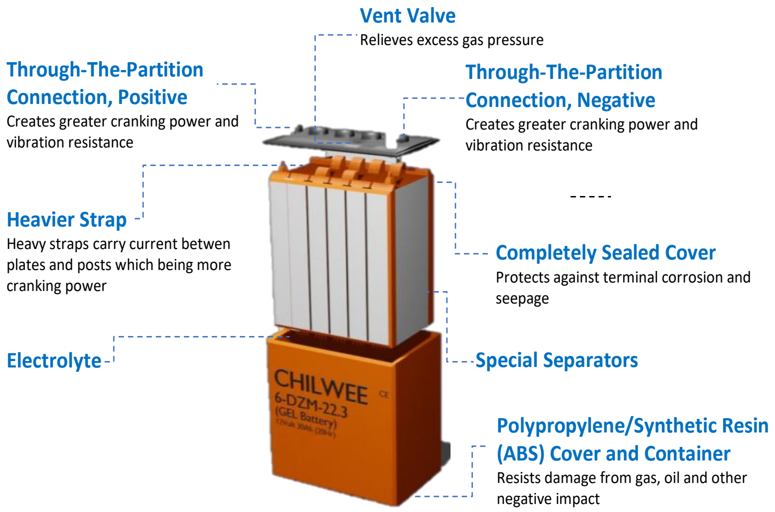


Fig. 2. Lead-Acid Battery

1.2 Sensor

The sensor monitors shunt current and power via an I2C- connection or an SMBus compatible interface. This sensor monitors shunt voltage drop and supply voltage (bus supply voltage), with programmable multiplication conversion and filtering. Programmable calibration values, combined with an internal multiplier, allow direct readings of current in amperes. Additional multiplier registers can produce power in watts. Some of the important features of the INA219 sensor are:

- Bus voltage from 0-26 V
- Can read current, voltage, and power
- High accuracy: 0.5%
- Has 16 programmable addresses
- Filtering options
- Calibration register
- SOT23-8 and SOIC-8 packages[12]

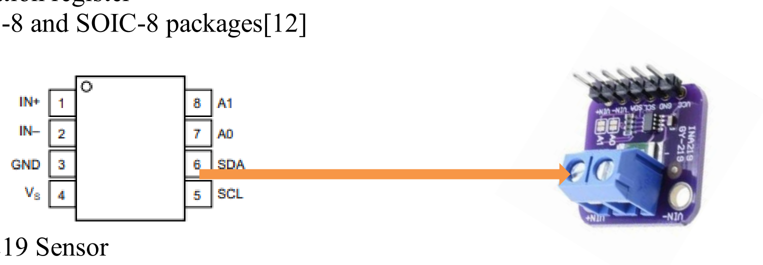


Fig. 3. INA219 Sensor

The INA219 sensor detects a shunt on the bus which can vary from 0 to 26V. The device uses a single supply of 3-to5.5V, drawing a maximum supply current of 1mA.

The INA219 operates from -40 °C to 125°C. The DHT-22 or AM2302 is a temperature and humidity sensor, this sensor has an output in the form of a digital signal with conversion and calculations carried out by the integrated 8-bit MCU. This sensor has accurate calibration with adjustment of room temperature compensation with coefficient values stored in the integrated OTP memory. The DHT22 sensor has a wide temperature and humidity measurement range, the DHT22 can transmit an output signal through the cable up to 20 meters so it is suitable to be placed anywhere, but if the cable is longer than 2 meters, a buffer capacitor of 0.33µF must be added between pin #1(VCC) with pin#4 (GND)[32].

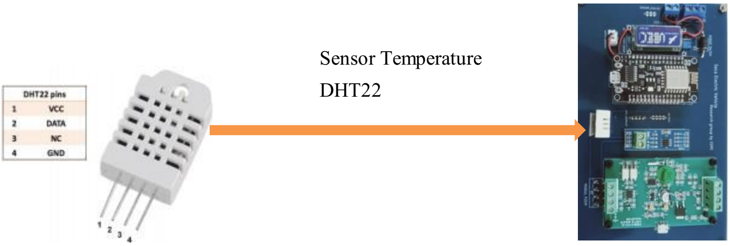


Fig. 4. INA219 Sensor

1.3. Microcotroller Node MCU ESP8266

Node MCU is an open-source IoT platform[33][34][35] Consists of hardware in the form of System On Chip ESP8266 from ESP8266 made by Espressif System, as well as the firmware used, which uses the Lua scripting programming language to assist in making prototypes of IoT products or can use sketches with the Arduino IDE. This development kit is based on the ESP8266 module, which integrates GPIO, PWM (Pulse Width Modulation), IIC, 1-Wire, and ADC (Analog to Digital Converter) all on one board. GPIO NodeMCU ESP8266 as Figure 5. NodeMCU measures 4.83cm long, 2.54cm wide, and weighs 7 grams. This board is equipped with WiFi and Firmware features that are open source. The specifications that are owned by NodeMCU are as follows:

This board is based on the ESP8266 serial WiFi SoC (Single on Chip) with onboard USB to TTL. The Wireless used is IEE 802.11b/g/n

- 2 tantalum capacitors 100 micro farad and 10 micro farad.
- 3.3v LDO regulator.
- Blue led as an indicator.
- Cp2102 USB to UART bridge.
- Reset button, USB port, and flash button.
- There are 9 GPIOs in which there are 3 PWM pins, 1 x ADC Channel, and RX TX pins.
- 3 ground pins.
- S3 and S2 as GPIO pins

- S1 MOSI (Master Output Slave Input) is the data path from the master and into the slave, sc cmd/sc.
- S0 MISO (Master Input Slave Input) is the data path out of the slave and into the master.
- SK is SCLK from master to a slave which functions as a clock.
- Pin Vin as input voltage.
- Built-in 32-bit MCU

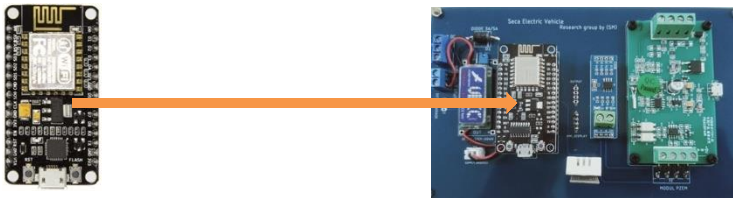


Fig. 5. GPIO NodeMCU ESP8266 v3

2. Human Machine Interface (HMI)

HMI (Human Machine Interface) is a system that connects humans and machine technology. HMI can be in the form of controlling and visualizing status either manually or through real-time computer visualization. HMI systems usually work online and in real-time by reading data sent through the I / O port used by the system controller. The ports that are usually used for the controller and will be read by the HMI include the com port, USB port, RS232 port and some use the serial port. The task of the HMI (Human Machine Interface) is to make a visualization of the technology or system in real terms. So that the HMI design can be adjusted to make physical work easier. The purpose of HMI is to improve the interaction between the machine and the operator through the computer screen display and meet the user's need for system information. HMI in the manufacturing industry is in the form of a GUI (Graphic User Interface) display on a computer screen that will be faced by machine operators and users who need machine work. data. HMI has various visualizations for monitoring and connecting machine data online and in real-time. HMI will provide an overview of the condition of the machine in the form of a map of the production machine which can be seen which part of the machine is working. In the HMI there is also a visualization of the engine controller in the form of buttons, sliders, and so on that can be used to control the engine properly. In addition, the HMI also displays an alarm if a dangerous condition occurs in the system. In addition, HMI also displays machine work summary data including graphical yield[36][37].

Fuzzy Logic

The fuzzy Mamdani Algorithm is a method with the idea of how to find a solution that is vague/grey. Lotfi Zadeh discovered the concept of fuzzy logic in 1964 with the premise that no state is "true" or "off". Each system output must have a gradation value between true or off by shifting the scale of a variable that can be measured as part of true or part of false. To take advantage of this situation, it is necessary to have a classical set theory based on extreme logic that can define objects as members or not members of the set. In fuzzy logic, an object can be a member of many sets with different degrees of membership in each set. The degree of membership in a set has a scale of 0 to 1[38]. Internet of Things (IoT).

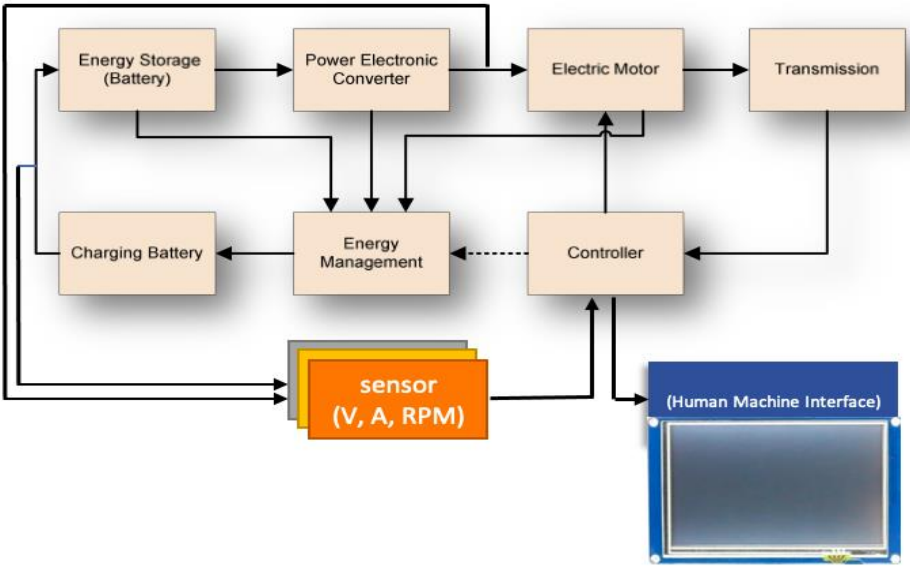


Fig. 6. Human Machine Interface (HMI)

Internet of things (IoT) is a concept that aims to expand the benefits of continuously connected internet connectivity. Internet of things (IoT) can be used in buildings to control electronic equipment such as room lights that can be operated remotely via computer networks, it is undeniable that rapid technological advances must be utilized, studied, and applied in everyday life. An example is the development of technology that can be utilized from the existence of an internet connection, which can access electronic equipment such as room lights that can be operated online via mobile. So that, can make it easier for users to monitor or control lights anytime and anywhere provided that the location where remote control technology will be applied has an adequate internet network. The remote control system makes it easier for users to control building lights that are located quite far away[39][40].

Resistive Load

A resistive load is a device that requires electrical power in the form of a component consisting of resistance (Ohms) and works or operates based on the working principle of resistance (resistance). The resistive load only uses active power and does not cause a change in the power factor value, so the power factor value remains, which is equal to one. Electrical devices that are included in resistive loads work based on the working principle of a resistor (resistance) so that the electric current that passes through it will be blocked and cause the electrical device to generate heat. The resistive load does not affect the voltage and current waves, so the voltage and current wave positions remain in phase.

Inductive Load

An inductive load is a device that requires electrical power in the form of a coil or coil of conducting wire wrapped around a coil core that works or operates on the principle of induction. Inductive loads use active power and reactive power. Inductive loads produce harmonic power which can result in a decrease in the value of cos phi to be smaller than 1.00 (<1.00). The coil in the inductive load causes the current rate to be inhibited, resulting in a shift in the position of the current wave to be lagging from the voltage wave

3. Discussion

3.1 Research Method

This research was conducted using an inductive load, namely an electric motor, and a resistive load, namely a lamp. The variables sought in this study are voltage, current, power, and temperature when the battery is charged and given a load so that the condition of the battery can be monitored completely. The battery used is a type of Valve Regulated Lead Acid brand MAXSTROM MS 12-12 which has a capacity of 12V12Ah/20HR.

3.2 Hardware Design

The hardware in this monitoring system is divided into three parts, namely the power sensor and temperature sensor as input, NodeMCU microcontroller as control, and HMI monitor as output.

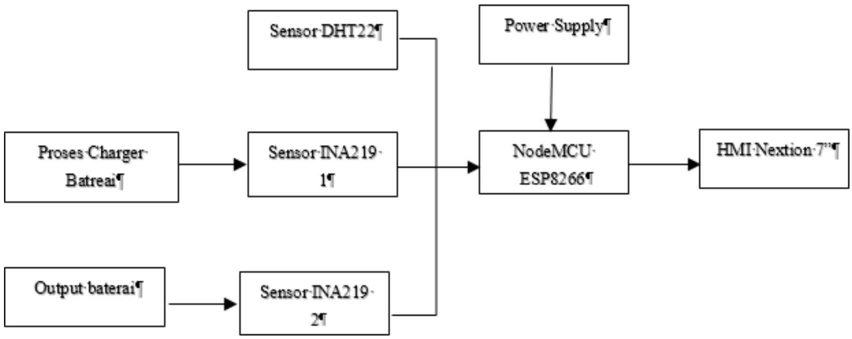


Fig.7. Block Diagram of Lead Acid Monitoring System

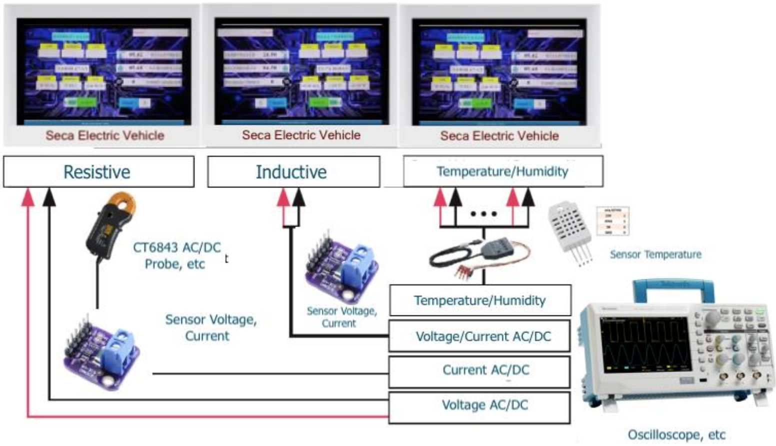


Fig. 8. Schematic Diagram of Lead Acid Monitoring System

3.3 Software Design

In the software, the command for monitoring is carried out by the controller, namely the NodeMCU ESP8266. When the lead-acid turns on or off, the current and voltage on the lead acid will be received by the input, namely the INA219 sensor which will then be received by the NodeMCU ESP8266 as input data and will be sent to the output, namely the HMI Nextion 7 Inch. Thus users can monitor lead acid easily. The program flow can be seen in Figure 9

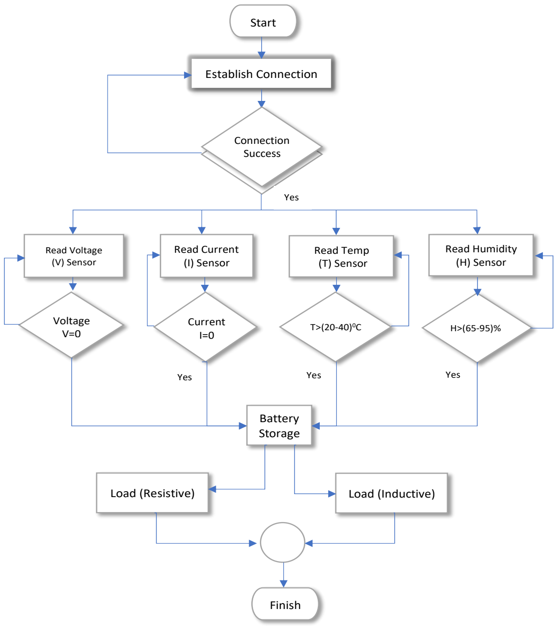


Fig .9. System Workflow Diagram

3.4. Results and Discussion

Battery Charging Monitoring System Results and Data.

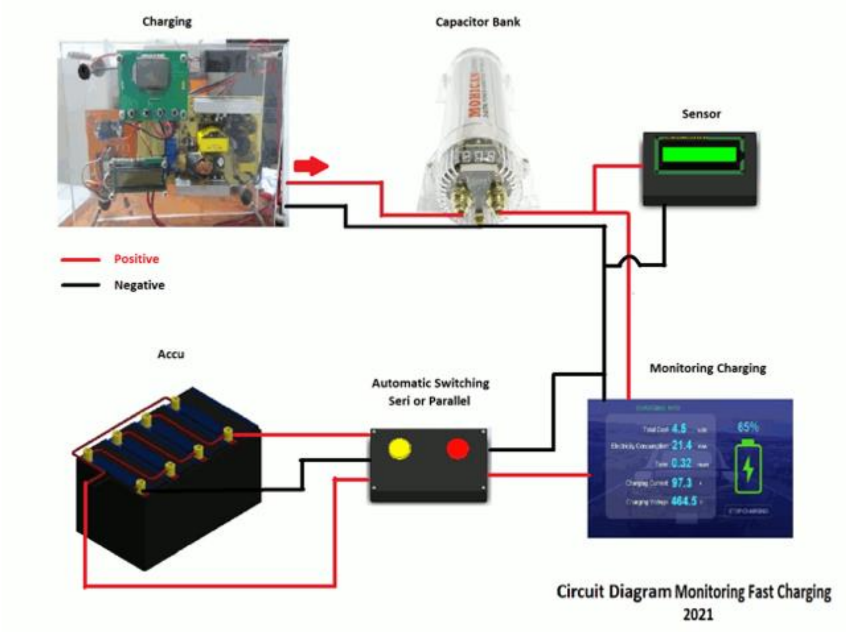


Fig .10. Battery Charging Test Block Diagram

Below are the results of monitoring current, voltage, and power when charging the battery which in this test uses a charger as input

Table 1. Test Results when charging the batter.

Times (s)	Voltage (V)	Current (mA)	Power (W)
1	11,7	2545,52	29,77
5	11,7	2543,25	29,75
10	11,7	2560,63	29,95
15	11,7	2549,32	29,82
20	11,8	2563,84	30,25
etc.	....	....	....
65	12,1	2860,97	34,36
70	12,2	2910,62	35,59
75	12,2	2930,28	35,74
80	12,2	2870,75	35,02
85	12,3	2860,32	34,4
90	12,3	2890,97	35,06
95	12,3	2850,58	35,06
100	12,4	2860,95	35,47

Please try to avoid rasterized images for line-art diagrams and schemas. Whenever possible, use vector graphics instead (see
Fig. 1).

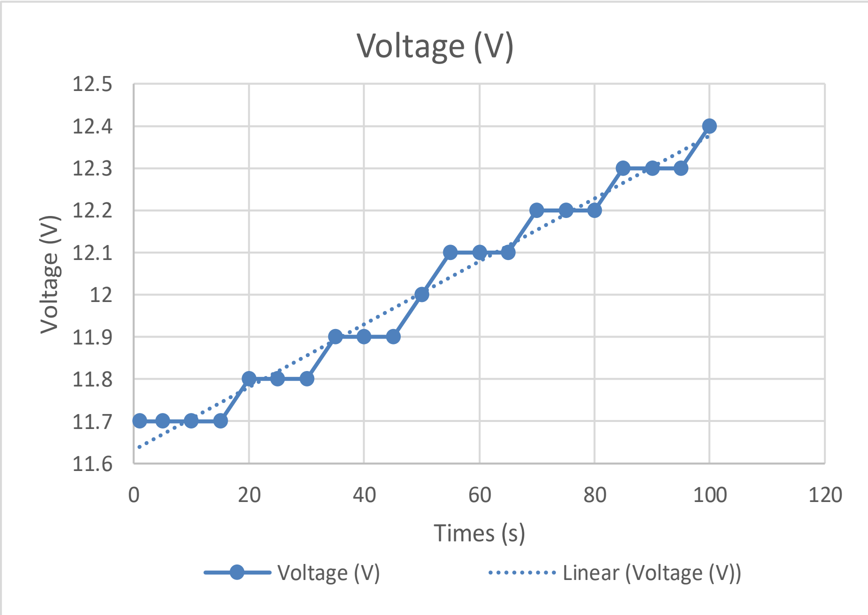


Fig. 11.. Graph of Voltage When Charging the Battery.

From the data above it can be seen that the voltage when charging the battery slowly increases to the point where the battery is fully charged. This is by the battery datasheet when it is charging.

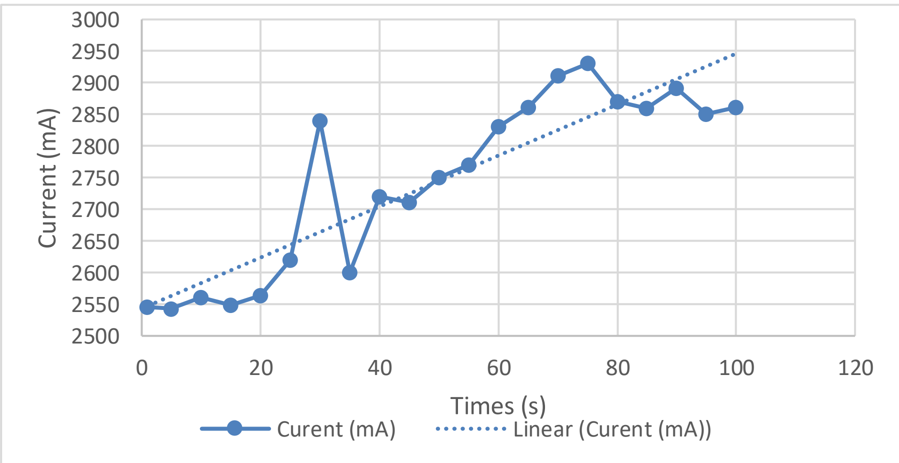


Fig. 12. Current When Charging the Battery

From the graph above, it can be seen that the current for charging the battery has increased significantly.

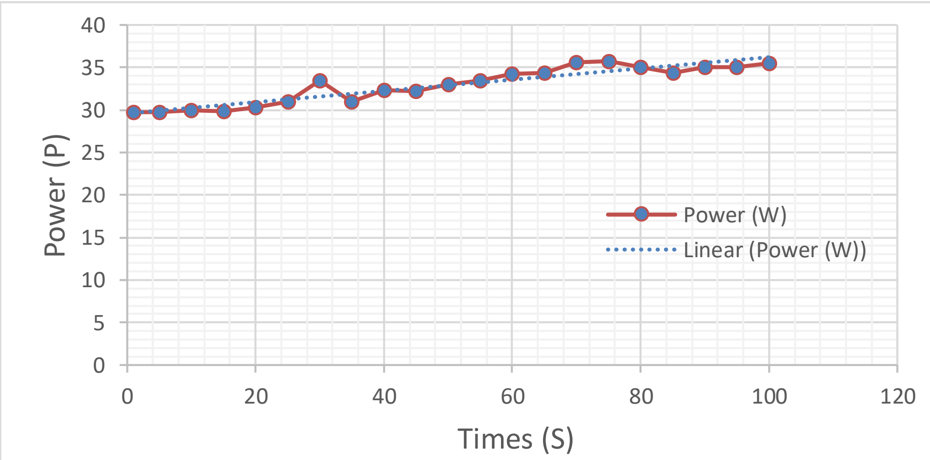


Fig. 13. Power while Charging

Resistive Testing Battery Monitoring System Results and Data

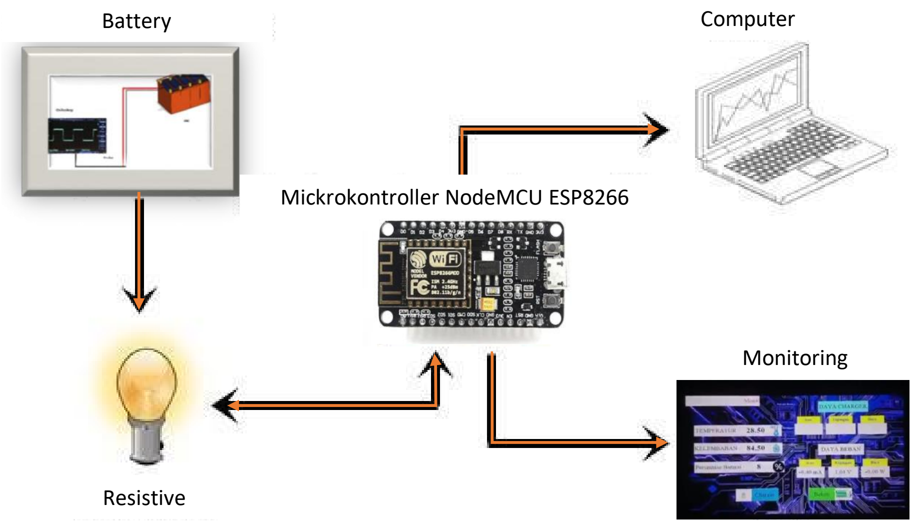
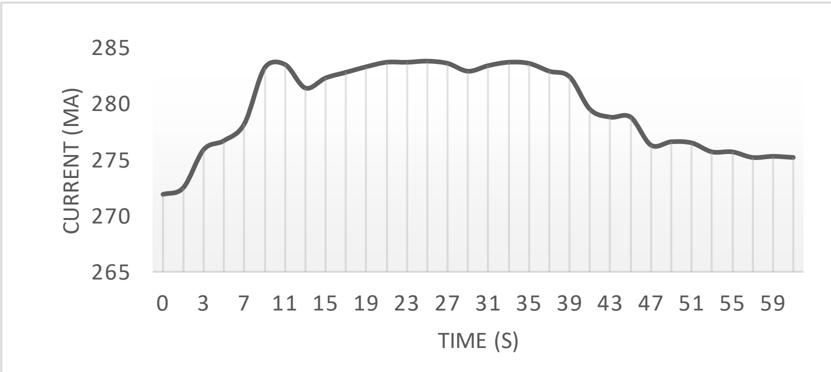


Fig. 14. Block Diagram of Resistive Load Testing

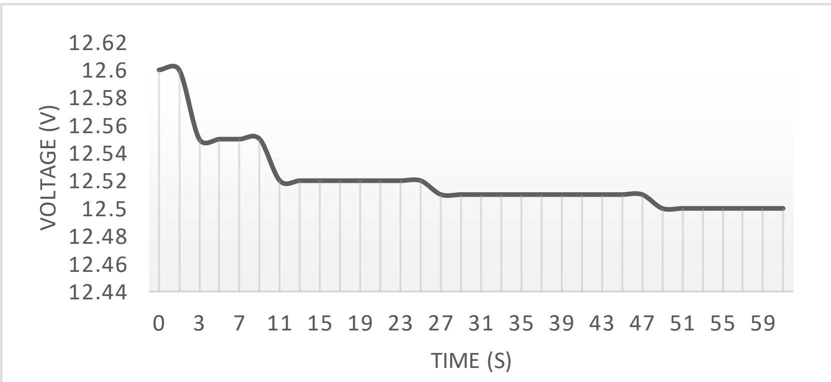
Below are the results of monitoring current, voltage, and power during resistive testing where in this test one lamp is used for one hour

Table 2. Results of the Battery Monitoring System during Resistive Testin

Times (s)	Voltage (V)	Current (mA)	Power (W)
0	271.9	12.6	3.42
1	272.5	12.6	3.43
3	275.9	12.55	3.42
5	276.7	12.55	3.47
7	278.2	12.55	3.49
etc	etc	etc	etc
57	275.2	12.5	3,44
59	275.3	12,5	3,44
60	275.2	12,5	3,44



(a)



(b)

Fig. 15. (a) Graph of Battery Current During Resistive Testing, (b) Battery Voltage During Resistive Testing

From the data above, it can be seen that the current in the battery when it is given a resistive load, in the early minutes of testing the increase is very significant. Then the battery current during resistive testing tends to be stable and gradually decreases, due to the discharge process in the battery. From the data above, it can be seen that the voltage on the battery during resistive testing tends to fall steadily. This is because the discharge process on the battery runs perfectly.

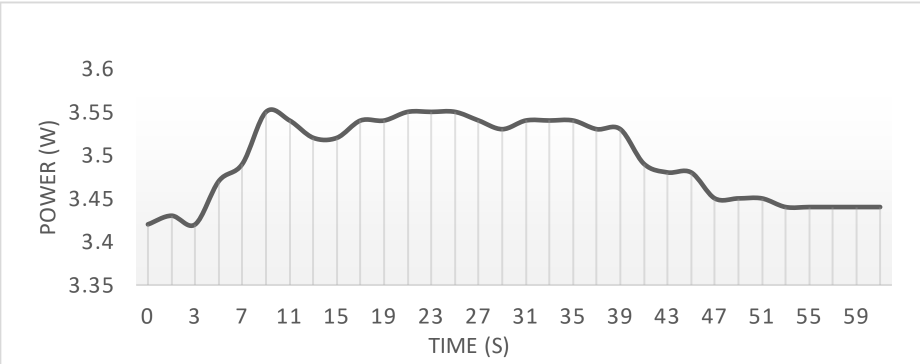


Fig. 16. Battery Power During Resistive Testing

The data above is the battery power at the time of resistive testing, it can be seen that the power in the early minutes of the test increased significantly, then stabilized and gradually decreased. This is because battery power is the product of the battery current and voltage.

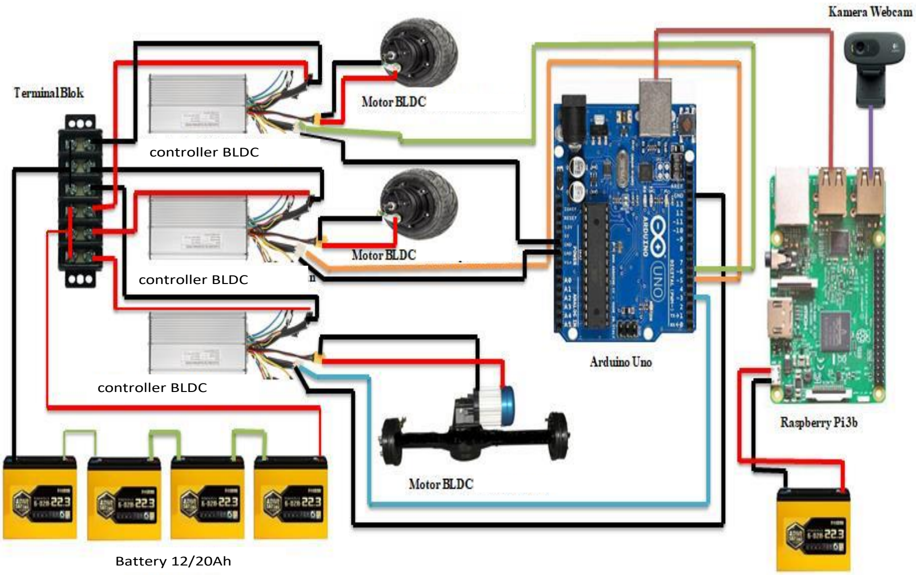
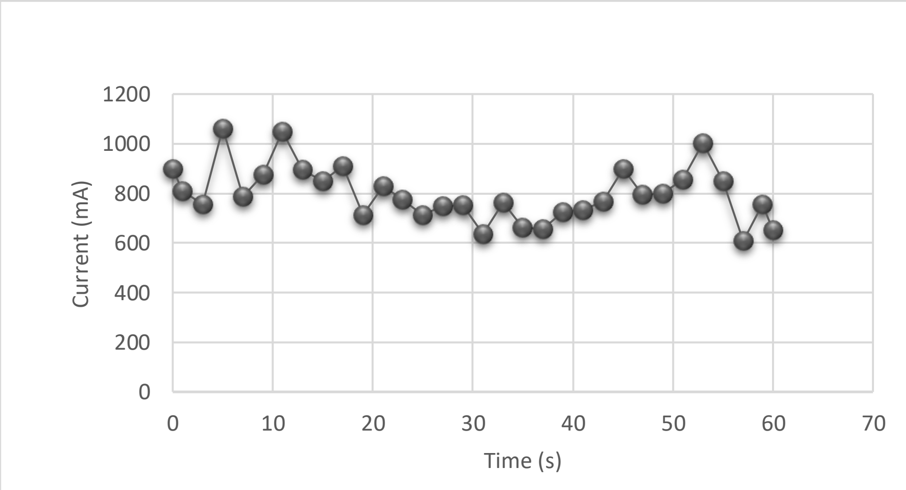


Fig. 17. Block Diagram of Inductive Testing

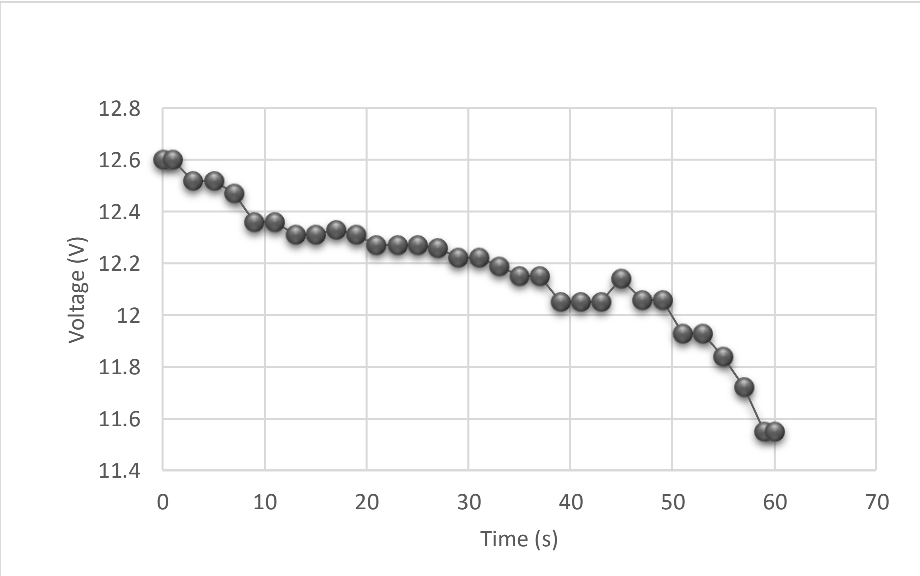
Table 3. Inductive Test Results Data

Times (s)	Voltage (V)	Current (mA)	Power (W)
0	900.3	12.6	11.16
1	809	12.6	10.03
3	757.5	12.52	9.39
5	1062.1	12.52	13.17
7	786.7	12.47	9.72
9	875.8	12.36	10.03
11	1051.2	12.36	12.99
etc	......	....	....
53	1001,9	11,93	11,95
55	849,8	11,84	10,03
57	607,9	11,72	7,17
59	755,2	11,55	8,93
60	653,1	11,55	7,72

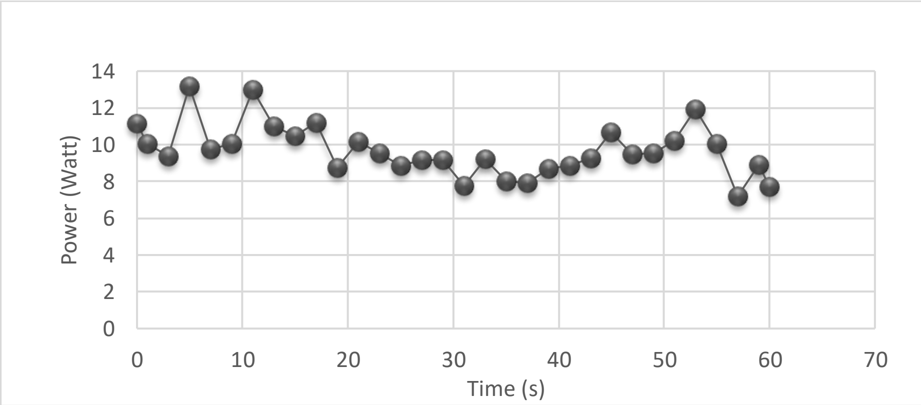
From the data above, it can be seen that the battery current during inductive testing tends to be stable, From the data above, it can be seen that the battery voltage when given an inductive load has decreased.


1200
1000
800
600
400
200
0
Current (mA)
0
10
20
30
40
50
60
70
Time (s)

(a)


12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
Voltage (V)
0
10
20
30
40
50
60
70
Time (s)

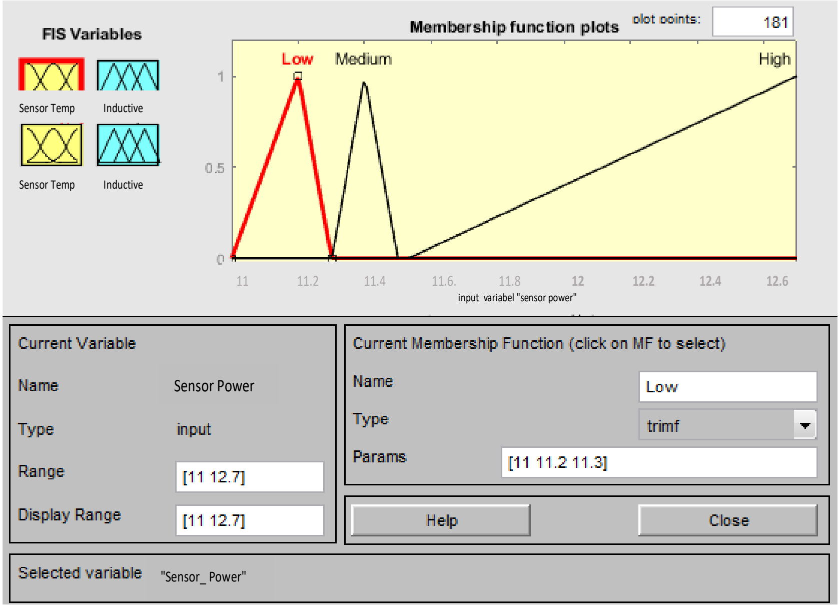
(b)



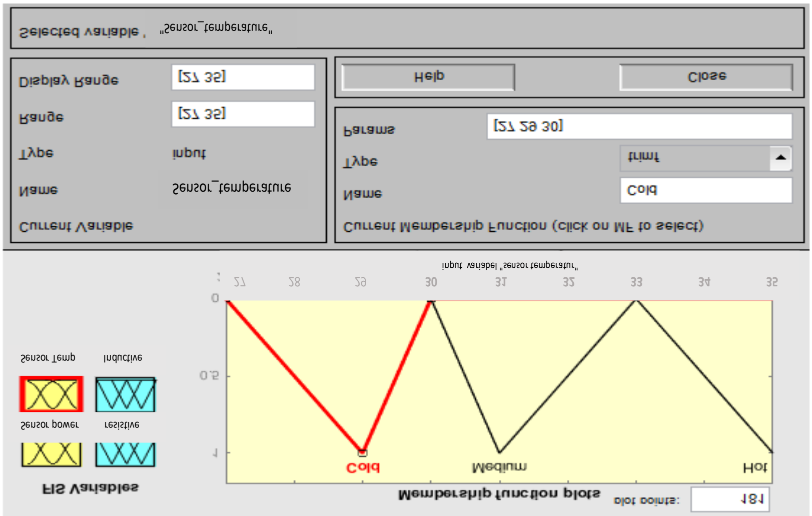
(c)

Fig. 18. (a). Battery Current During Inductive Testing, (b). Battery Voltage During Inductive Testing, (c). Battery Power During Inductive Testing

Determining Resistive and Inductive Load Conditions During Testing Based on Fuzzy Logic.

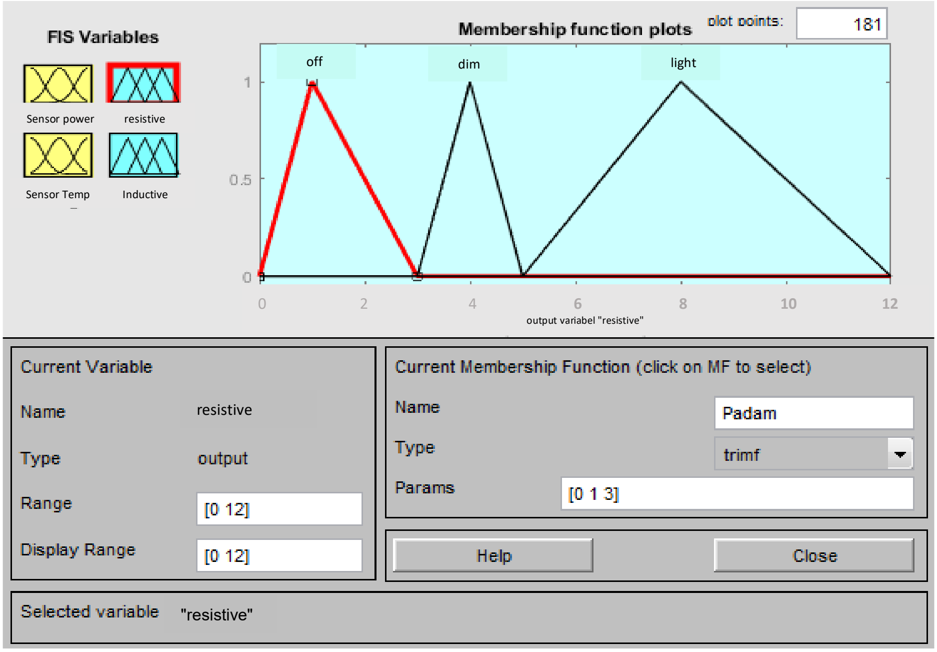


(a)

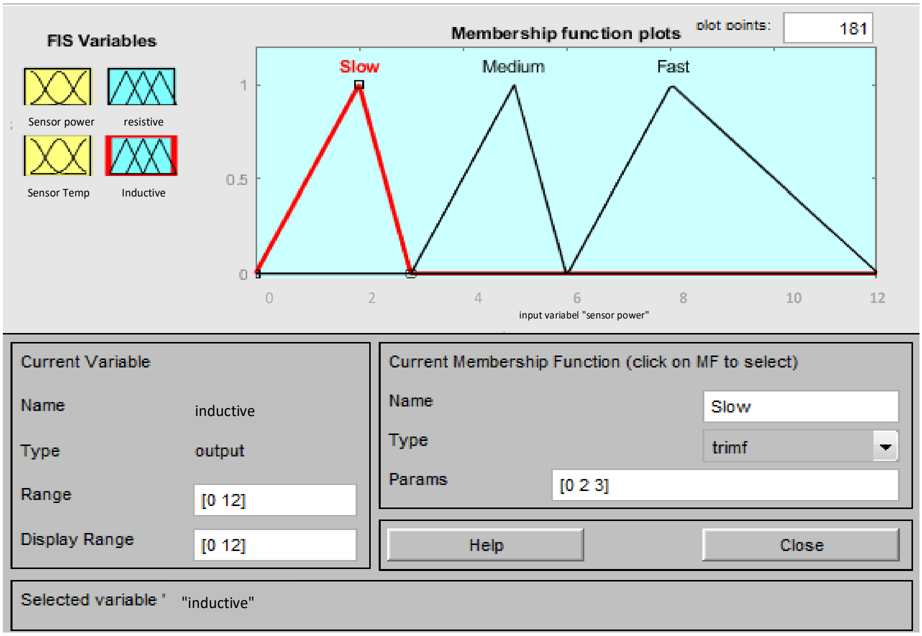


(b)

Fig. 19. (a) Membership Function Input Power Sensor, (b) Membership Function Input Temperature Sensor



(a)



(b)

Fig. 20. Membership Function Output (a) Resistive Load, (b) Inductive Load

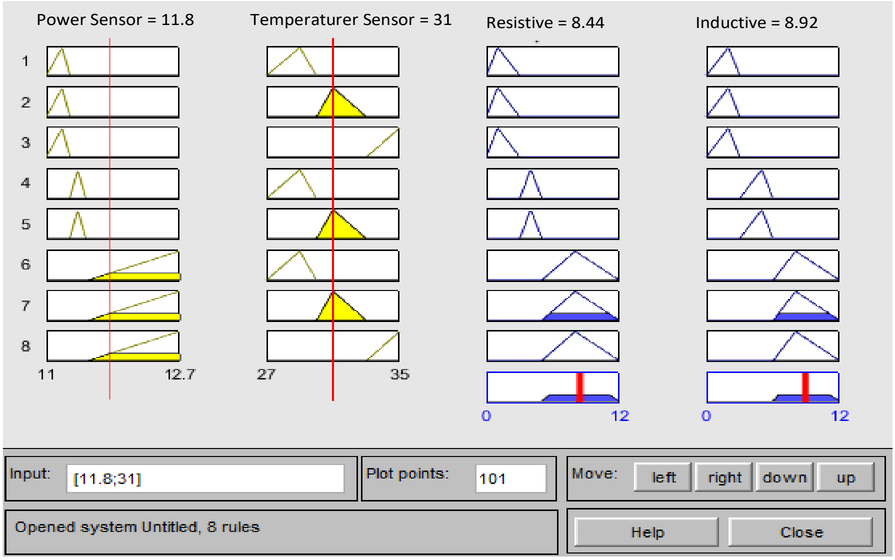
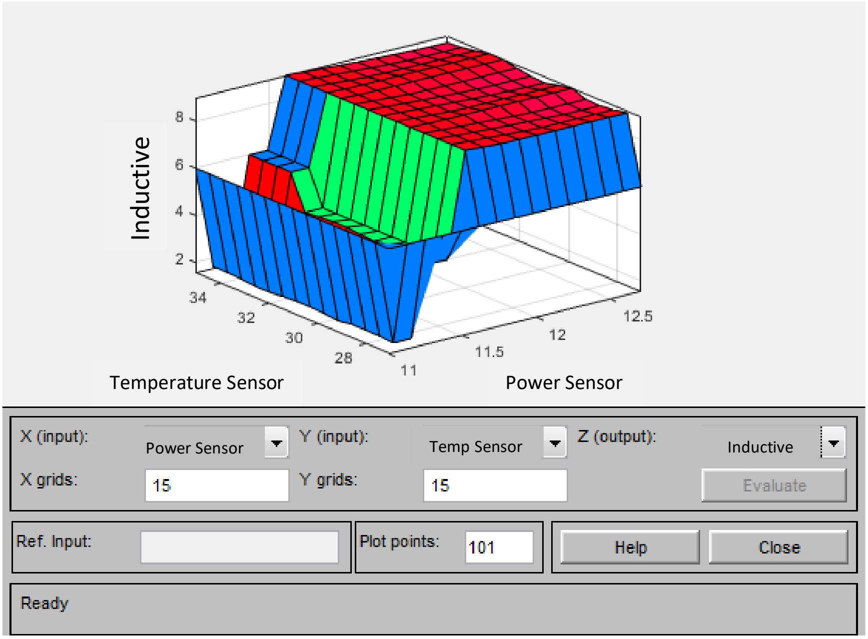
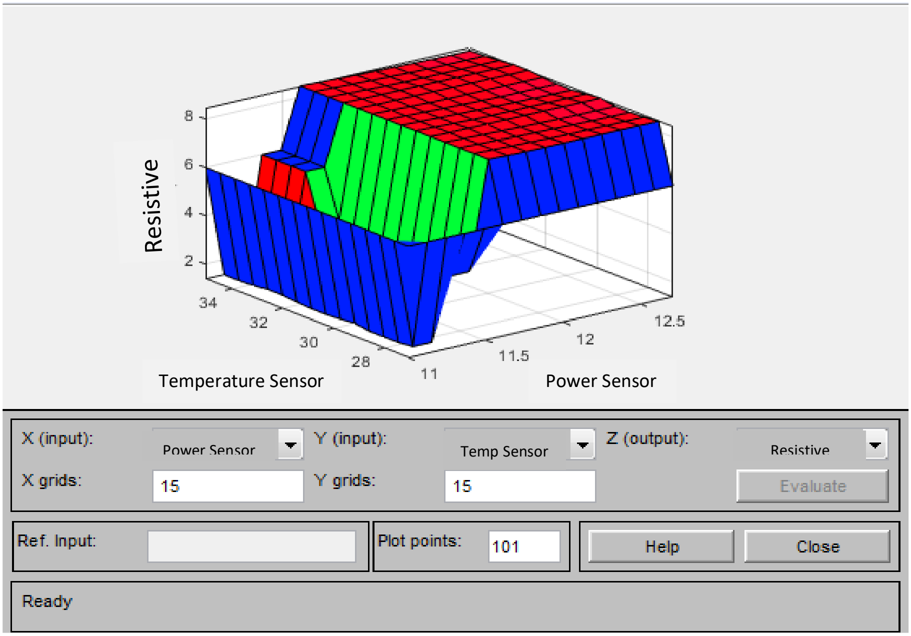


Fig. 21. Graph of Rule Base Fuzzy Logic Lead Acid Battery Monitoring System



(a)



(b)

Fig. 22. (a) Graphics Fuzzy Logic Resistive Output Battery Monitoring System, (b). Graphics Fuzzy Logic Inductive Output Battery Monitoring System

CONCLUSION

Based on the results of testing this battery monitoring system tool it can be concluded: The battery used in this study is still in good condition because the voltage on the battery is in normal condition. The power sensor used can accurately detect voltage, current, and power in the battery. The temperature sensor used can accurately detect the temperature and voltage in the battery. The sensor data used can be displayed to the HMI monitor in real. Based on the results of testing this battery monitoring system tool it can be concluded: The battery used in this study is still in good condition because the voltage on the battery is in normal condition. The power sensor used can accurately detect voltage, current, and power in the battery. The temperature sensor used can accurately detect the temperature and voltage in the battery. The sensor data used can be displayed to the HMI monitor in real

The parameters to be measured in the battery management system are State of Charge (SOC) and Depth of Discharge (DOD). The method that will be used to obtain State of Charge (SOC) and Depth of Discharge (DOD) is Fuzzy Logic.

Authors' Contributions

Implementation of charging with the Fuzzy Logic model on SECA Lead Acid Batteries.

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