A New Method in Performance Test of Electric Vehicle Battery Using Water Rheostat

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Abstract: Nowadays, the electric vehicles uses is increased, both for private and public transportation. The electric vehicles increasing is supported by the battery technology innovation. A reliable, inexpensive and large capacity of the battery are created but less attend to battery instrument to review the real battery performance. This paper are discussion a new method in performance test of electric vehicle battery using water rheostat to review the real battery performance. The water rheostat are consist of two set aluminum electrode plate. To increase the current discharge value is done by added water to soak the electrode plate. The data logger collected the voltage, and discharge current of times. The data analysis indicated this water rheostat dummy load have a good performance to instrumented the battery performance. The finding of this paper is: 1. The discharge current are inversely proportional with the battery terminal voltage. 2. On the discharge current value is 2.17 Ampere in voltage 83.64 volt, the water resistivity is 2,698.06 Ohm-meters and than go down to 73.87 Ohm-meters on the voltage value 46.00 Volt and the discharge current 43.53 Ampere. 3. The discharge current a inversely with the area of electrode. 4. The water resistivity are linear function to the resistance of water rheostat. 5. Water rheostat with two sets of electrodes dimensions of 35 x 36 centimeters can be use as a dummy load of up to 2.3 KW in a voltage of 66 Volt DC.

1 INTRODUCTION

Nowadays, the use of electric vehicles is growing, both for private and public transportation. The electric vehicles using is in line to the Bali State Polytechnic as a centre of excellence for green tourism technology. Electric vehicles are chosen at this time because they do not cause noise pollution, low operating costs, and light vehicles (Srinivas, 2019). The growth in the use of electric vehicles contributes to pollution reduction, cost efficiency, reducing road damage due to lighter electric vehicles (Sudjoko,2021). The very worrying pollution caused by the vehicles age and engine combustion system has a strong correlation in producing CO and HC values (Dinda et al., 2020). Electric vehicles would reduces air pollution like nitric oxide (Daniel et al., 2021; Ernani F. at al., 2020)

Pollution remains unresolved even though efforts have been made to utilize the radiator heat as a heat source to heat the combustion system (Wiryanta, 2019). The electric vihicle must growing, the electric vehicles growth is supported by the growing of cheap design of batteries, so that the price is cheap, large capacity and long life (Michael et.al, 2018). Various shapes, types and capacities of batteries are made by industry. The dimensions of the battery are smaller but with greater capacity. To support the performance of electric vehicle batteries, smart charging has been designed to improve battery performance (Bowen, 2019). The greater battery capacity, affect to the longer times to use the battery for the same load. There are also a lot of batteries sold in retail, so technicians can assemble custom batteries as needed. Vehicle battery customized can be done in terms of shape and capacity requirements.

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The electric vehicles growing, has been supported by the construction of charging centers also (Zhuk A and Buzoverov E, 2018). The inventions of design and control batteries charging gave rise to increasingly sophisticated charging stations. The current sophistication of charging stations makes it easy for electric vehicle users to recharge their batteries. Ease is felt in the ease of connection without having to open the battery. The sophistication of the charging station is also evidenced by the shorter charging time of the battery for the same capacity. The sophistication of the charging station is also supported by the sophistication of the control battery management system (BMS) which can control the condition of the battery carefully and smartly because through a bluetooth device the battery condition status can be monitored remotely from a smart phone. Industries and researchers, while that instrument is very important to guarantee the quality of batteries, because the battery has come from various factories. Battery is also to many much implemented for solar power generation (Wirajati et al., 2021) . The Dummy Load as described in this paper is a solution to get a battery capacity test instrument.

2 RESEARCH METHOD

2.1 Research Approach and Concept

This research was designed as a quantitative approach study to find the design of a water rheostat, which can be used as an artificial load in testing battery quality. This water rheostat is designed by utilizing the resistivity of water to soak two positive and negative electrode plates.

The concept of this research is applied research, by applying the basic law of Ohm's law and the resistance formula, into a water rheostat, the area of this resistor is largely determined by the area of the electrode plate and the limit distance from the electrode plate, to solve the problem of the absence of a battery test instrument with inexpensive but large capacity. The wider the plate electrode affect to decreasing the resistance value, this ratio is in line to the conductor, the wider area of the conductor affect to the smaller of the resistance value. Likewise, the smaller the distance between the negative plate and the positive plate affect to the decreasing the resistance value, this is in line with the conductor, the shorter of the conductor affect to the smaller of the resistance value. The small resistance of the water rheostat will be a big load for the battery, the parallel connection of several electrodes decreases resistance value.

2.2 Total Sample

This research was conducted with a sample of water rheostat, the collection was carried out with a total of 20 data for each indicator. To take the 20 of data is done by regulated the water level from zero to maximum and measured the value of voltage and current flow to the water rheostat.

2.3 Variable Operational Definition

The focus of this study to observing the magnitude of the variable of this research, that are : The first independent variable is the area of the electrode that is soak in the water, and the second is the time of testing. Meanwhile, the first dependent variable is the discharge current of the battery increases caused by the increased the area of the electrode soak in water, and the second dependent variable is the voltage are decreases caused by the increases of discharge current of the battery. Voltage is amount in volt of potential test voltage between two terminal of the battery. The current is amount in ampere of electron flow to the electrode. The area of the electrode in square meters is obtained by measuring the depth of the water multiplied by the width of the electrode plate multiplied by the number of electrodes inserted into the water.

2.4 Data Analysis

Data obtained from the test results are processed quantitatively. Data is processed mathematically and statistically by finding the data variation on the step by step the water level. The data are processed mathematically to obtain the voltage and current discharge at the initial of the test, and finally when the water box is fully, the test is stop. The output mathematically data is processed trough statistically to obtain the average data, data sequence, which is also displayed graphically.

3 WATER RESISTIVITY

All of materials have electrical properties characteristic, such as resistivity, likewise water has resistivity properties. The resistivity of water causes an low electric flow current in the water even though that it is not as smooth as an electric current flowed in gold or copper. This water resistance property can be utilized for low resistors with large power capacities.

The resistivity of water used in low voltage power machinery and other heavy equipment laboratories, there is a universal need for a compact, rugged, yet flexible and continuously variable rheostat (Engle, 1952). This water rheostat are available for so many applications as: dc motor starting, dc and ac single and 3-phase loading, wound-rotor induction motor speed control. Water rheostat like balanced 3-phase load, that is equivalent delta AC circuit, water rheostat which also may be used in DC and AC single-phase circuits. The untreated city tap water that has an average resistivity of 4,600 ohms per inch cube at 20° Centigrade, and for a single rheostat unit will dissipate up to 75 kw (Engle, 1952). The resistivity of water is strongly influenced by the substances contained. Water with a higher salt content will have a lower resistivity. The low resistivity of this water can be used to make a water rheostat with a higher capacity.

Water rheostat has the potential as an dummy load with a very large capacity if a large capacity water reservoir is provided. to increase the capacity can be done by expanding the electrodes used, increasing the volume of water. Because the water resistance (R) is strongly influenced by the resistivity of water (ρ), the area of the electrode (A) and the distance between the electrodes(l), which can be explained by the formula below.

$$R = \frac{\rho \, . \, l}{\mathrm{A}} \tag{1}$$

Based on formula (1) above, it can be explained that to get a low resistance (R) of the water rheostat, it can be done by expanding the surface area of the water (A) in contact with the electrode surface. On the other hand, to get a higher resistance (R) of the water rheostat, it can be done by narrowing the surface area of the water (A) in contact with the electrode surface. While Ohm's law states that voltage (V) is strongly influenced by current (I) and resistance (I), if a substitution is made, the amount of current (I) that flows is strongly influenced by voltage (V) and is best proportional to resistance (R). The substitution results for Ohm's law can be assumed by formula (2) below.

$$I = \frac{V}{\mathrm{R}} \tag{2}$$

Meanwhile, the power (P) released by the battery is strongly influenced by the current flowing (I) and the resistance value (R) through which the current flows, this opinion can be explained by the formula below.

$$P = V . I \tag{3}$$

Based on formula (3) it can be explained that to be able to discharge the electric power (P) in the battery, it is done by increasing the current (I) flowing at the same voltage (V). So to regulate the amount of discharge power is done by increasing the flowing current. while in ohm's law as outlined in formula (2) the value of the current (I) that flows will be greatly influenced by the resistance value (R), the smaller the resistance value, the current value will increase at the same voltage. So based on formulas (1) (2) and (3) it can be understood that to be able to deliver a large discharge power (P) it can be done by reducing the resistance value by expanding the surface (A).

4 THE WATER RHEOSTAT DESIGN

To make a water rheostat, components are needed, including: water box, electrode plate, plate barrier, tie fasteners, nuts and bolts, cables and cable shoes. Data Logger is used to record the value of current and voltage within a certain time interval. The shape of the water rheostat can be depicted in the following figure at below.

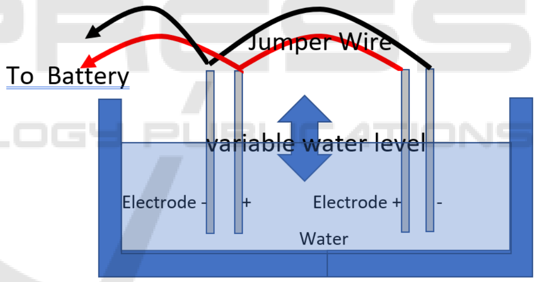

Figure 1: Water rheostat diagram.

Like in the figure 1 can be describe the red cable is connected to positive of the battery terminal and electrode, the black one is connected to negative of the battery terminal. In the connected condition between the battery terminal with the wet electrode, the current will be flowed from positive terminal to the positive electrode, trough the water from positive to negative electrode, the finally to negative terminal of the battery. This current flowed process will discharge the energy in the battery.

The high or low current flowed affected to the duration time of discharge process(Ioannou et all., 2017). The high flowed current affected to the faster discharge, and than the low current flowed affected to the lower discharge process. The high of the current flow depend the water rheostat resistance. The low of water rheostat resistance affect to the high current flow, and the high water rheostat resistance affect to low current flow.

The high or low of water rheostat resistance depended of the water level to burial the electrode in the fixed of the space between positive electrode dan negative electrode. The high of water level will be reduced the water rheostat resistance and the lower one will be upgrade the resistance. Like as described to fix water rheostat resistance, must be keep the water level. The water rheostat must be designed by the system to keep the water level like in figure at below.

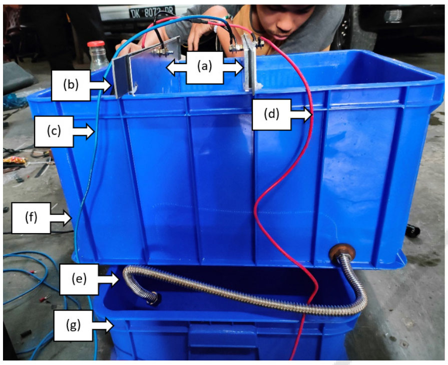

Figure 2: Water rheostat design.

As shown in the figure 2, the main component of water rheostat consists of: electrode, water and box. The detail of the water rheostat design consists of: (a) two set electrode as dummy load, (b) fresh water supply pipe to keep the water level, (c) negative cable to connected the battery terminal, (d) positive cable to connected the battery terminal, (e) overflow pipe to control the level of water, (f) main water box to collect the water capacity, (g) reservoir to collect the over flow water.

5 RESULT AND DISCUSSION

The results of the research are shown in numbers arranged in a table. The data from the test results are discussed by analysing mathematically and statistically, which is finally displayed in the form of a graph.

5.1 Result

The study was conducted by testing a battery with a voltage stated on the nameplate of 72 Volt 30 amperes hours. The battery is charged first to full, after being fully charged the battery is discharged by connecting the battery to a water rheostat via a miniature circuit breaker as shown in the figure below.

The test is carried out as shown in Figure 3 below. The red wire is connected to a positive voltage source, while the black wire is connected to a negative voltage source. The test was carried out using two sets of water rheostat electrodes.

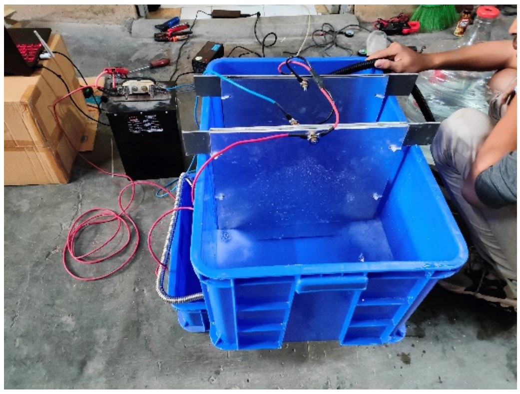

Figure 3: Tested process.

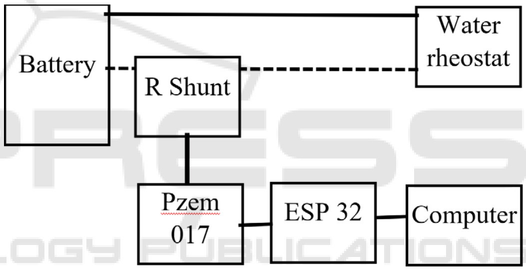

Figure 4: Block diagram.

The analogue Voltage and current flowing to the electrodes are converted to digital by a DC communication module which can measure DC power up to 300 VDC and current measurement in an external shunt mounting range of 50A to 300A. The measurement results are processed by the Pzem-017 converter and read by the ESP-32 data logger, the data is then sent to the Blynk application on the computer to displayed the value of the voltage, current, Power, energy, time at below and also on Google Spread Sheet as shown at the figure 5. The data from this spreadsheet is then taken as much as 20 data according to the water level step in the box as describe on the table 1. The electrode used in this study is aluminium material, with a thickness of 3.5 cm.

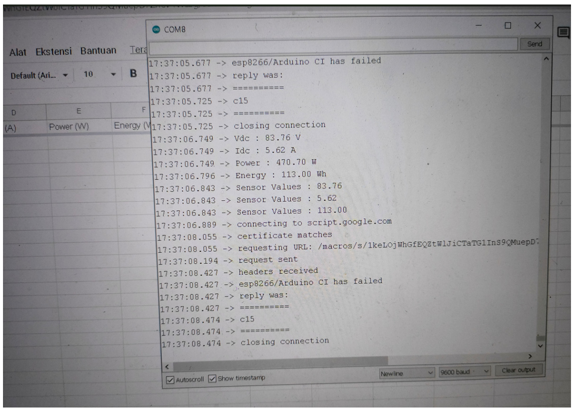

Figure 5: Measurement display.

Table 1: Test result.

Voltage (Volt)	Current (Amp)	Water Deep (M)	Duration (second)
83.64	2.17	0.02	180
82.62	4.35	0.04	180
81.60	6.53	0.06	180
80.61	8.71	0.08	180
79.62	10.89	0.1	180
78.64	13.07	0.12	180
77.68	15.25	0.14	180
76.73	17.43	0.16	180
75.79	19.61	0.18	180
74.86	21.79	0.2	180
73.94	23.97	0.22	180
73.03	26.15	0.24	180
72.14	28.33	0.26	180
71.25	30.51	0.28	180
68.00	32.69	0.3	180
66.00	34.87	0.32	180
60.00	37.05	0.34	180
56.00	39.23	0.36	180
50.00	41.41	0.38	180
46.00	43.59	0.4	180
Total			3600

5.2 Discussion

Based on the data in table 1, the area of the submerged electrode can be calculated as follows:
Electrode width : 0.35 meters
Water deep : 0.02 meters
The area is = 0.35 x 0.02
= 0,007 ~ 0,01 meter^2

The power discharge of the battery can be explained by the formula below.

$$P = V.I$$

$$P = 66\ x\ 34.87 : 1000 = 2{,}3\ KW$$

Resistance which can be explained by the formula below.

$$R = \frac{\rho\ .\ l}{\mathrm{A}}$$

The water resistivity which can be explained by the formula below.

$$\rho = \frac{R\ .\ A}{l} = \frac{V\ .A}{\mathrm{I}\ .\ l}$$

$$\rho = \frac{83.64\ .\ 0.01}{2.17\ .\ 0.001} = 385\ Ohm\ Meter$$

Through the same analysis as above, this study found the value of electrode area, water resistivity, and load like in the table 2 at below.

Table 2: Analysed electrode area and water resistivity.

Electrode Area (M^2)	Load (KW)	Voltage (Volt)	Current (Amp)	Water Resistivity (Ohm-m)
0.01	0.18	83.64	2.17	2698.06
0.03	0.36	82.62	4.35	1329.46
0.04	0.53	81.60	6.53	874.78
0.06	0.70	80.61	8.71	647.81
0.07	0.87	79.62	10.89	511.78
0.08	1.03	78.64	13.07	421.19
0.10	1.18	77.68	15.25	356.56
0.11	1.34	76.73	17.43	308.14
0.13	1.49	75.79	19.61	270.53
0.14	1.63	74.86	21.79	240.48
0.15	1.77	73.94	23.97	215.92
0.17	1.91	73.03	26.15	195.50
0.18	2.04	72.14	28.33	178.24
0.20	2.17	71.25	30.51	163.47
0.21	2.22	68.00	32.69	145.61
0.22	2.30	66.00	34.87	132.49
0.24	2.22	60.00	37.05	113.36
0.25	2.20	56.00	39.23	99.92
0.27	2.07	50.00	41.41	84.52
0.28	2.00	46.00	43.53	73.87
Average		71.41	22.88	453.08

Figure 6 shows that when the discharge current increases, the battery voltage drops(Changseng L. and Xingxing Z., 2022). Drastic drop in battery voltage at loads above nominal battery current. The loading is done repeatedly like figure 6, it is estimated that the discharge current will decrease, so that can be predicted of the life cycle of the battery.

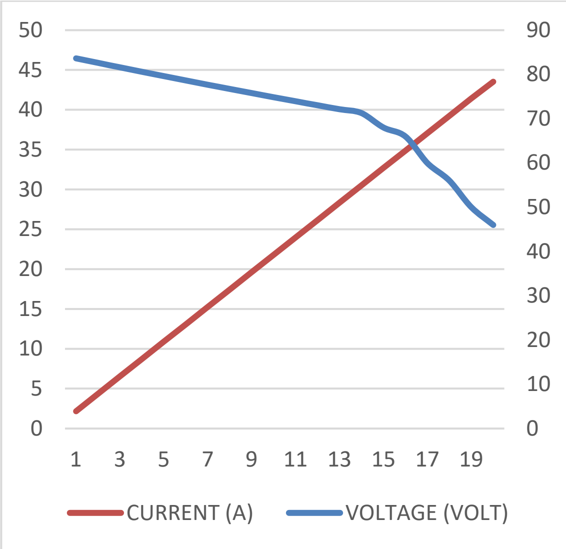

Figure 6: Voltage and current are inverseley proportional.

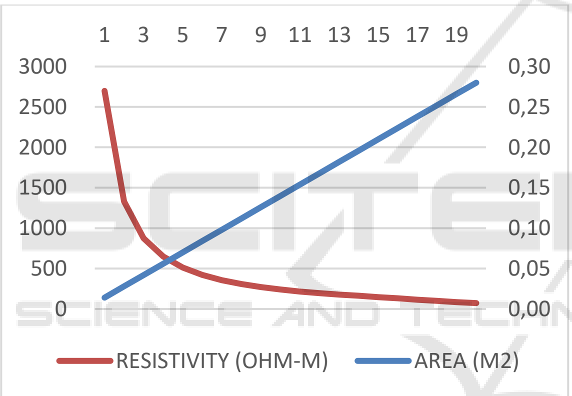

Figure 7: Water resistivity graph.

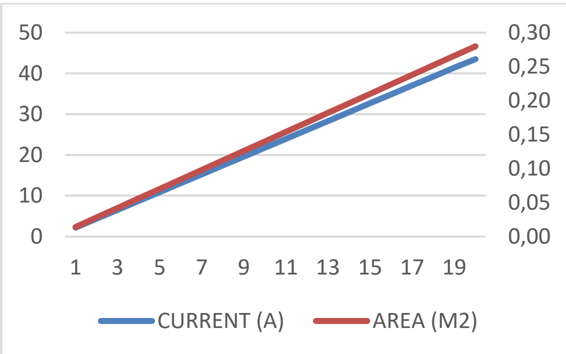

Figure 8: Current and Area Linearity.

The battery sample tested in this study was a 72 Volt (30 Ah) battery. Based on table 2, the average battery voltage is 71.41 Volts, with an average discharge current of 22.88 Amperes, within 1 hour, so the real battery capacity being tested is according to the calculation below.

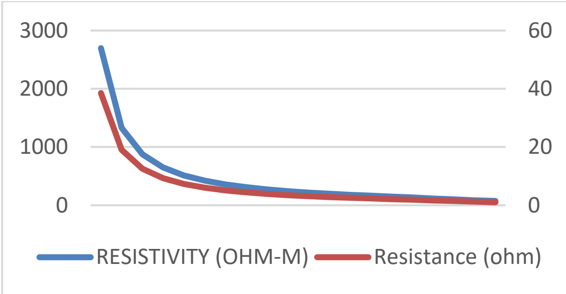

Figure 9: Water resistivity and resistance of water rheostat.

$$W(\%) = \frac{V1.I1.t}{V2.I2.t} x100\%$$

$$W(\%) = \frac{72 \ x \ 30 \ x \ 1}{71.41 \ x \ 22.28x1} x100\% = 74.59\%$$

If this test is done repeatedly, it will result in a decrease in battery performance, so that the battery life can be predicted graphically (David, 2019).

6 CONCLUSIONS

Based on the results of testing and analysis can be concluded as follows:

1. The discharge current are inversely proportional with the battery terminal voltage.
2. Portion the discharge current value is 2.17 Amperes in voltage 83.64 volt, the water resistivity is 2, 698.06 Ohm-meters and than go down to 73.87 Ohm-meters on voltage 46.00 Volt and the discharge current 43.53 Amperes.
3. The discharge current a inversely with the area of electrode.
4. The water resistivity are linear fuction to the resistance of water rheostat.
5. Water rheostat with two sets of electrodes dimensions of 35 x 36 centimeters can be use as a dummy load of up to 2.3 KW in a voltage of 66 Volt DC.

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