Estimation of Battery Capacity using Voltammetry Method of Lead Acid and Nickel Cadmium Battery based LMNN at Jember Electric Substation

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Keywords: Lead Acid Battery, Neural Network, Nickel Cadmium Battery, Voltammetry cyclic.

Abstract: The reliable battery holds a very important role. Therefore, this refers to study the characterization of lead acid batteries and nickel cadmium, this is a secondary battery of the most developed and the lead acid batteries are widely used in the automotive field. The lead acid and nickel cadmium battery capacity is determined by the amount of electrical charge that is obtained from the battery and the amount depends on the active ingredient contained in the plate. To determine the characterization and capacity lead acid battery and nickel cadmium battery are suitable for use, this study used two methods. With voltammetry analysis and development the lead acid battery model design based on neural network method. In the electrochemical field the voltammetry cyclic is a condition when the current is measured during a sweep potential from the beginning to the end potential and then back again. It is also called sweeping or scanning and can be reversed after the reduction takes. So the anodic and cathodic current can be measured. Then the design of the model development lead acid battery based on neural network in this study using inputs specifically the voltage as input, and the current as target. So the accuracy testing of the forecasting system using neural network algorithm will be better and more efficient than the experiment data manually.

1 INTRODUCTION

This Lead acid batteries are composed of lead dioxide as the cathode, a metal sponge as the anode lead and sulfuric acid as the electrolyte. Each cell has a voltage of 2 volts. Advantages of the use of lead acid batteries which are robust, inexpensive, reliable, tolerant of excess charging, low internal impedance. While the lack of a battery of this type which are very heavy, have low energy efficiency of about 70 %, dangerous overheating during charging, have a lower cycle time is 300-500 cycles, and materials are harmful to the environment (Al-Atas, H. M., 2015).

Then nickel cadmium battery This type of battery has a cell voltage of 1.2 Volt per cell with twice the energy density of lead acid batteries. As a cathode, this battery uses nickel hydroxide $Ni(OH)_2$ and cadmium Cd as anode possessed by alkaline potassium hydroxide as its electrolyte. Nickel cadmium batteries have a resistance. Which is very small and allows for the charge and discharge with a high level (Husain, I., 2003). Meanwhile, according to SK520 PLN nickel cadmium batteries or Ni-Cd is alkali battery with a capacity of 1.2 volts per cell and is often used in PT. PLN as a DC provider of protection systems, SCADA and PLC (KEPDIR 0520-2 K DIR, 2014)

With these descriptions, the authors will discuss about Development Voltammetry Based LavenbergMarquadtNeural Network (LMNN) Method. The purpose of this research is to determine the capacity of a lead acid battery and nickel cadmium battery and also to know how to increase the capacity of lead acid batteries with a constant voltage, so we could get more efficient lead acid battery.

2 EXPERIMENTAL

The lead acid batteries will be measured and appliedby using Pulse Voltammetry cyclic method. In this voltammetry measurement, the working electrode use a pure Pb sheet. In order to remove the oxide layer of the Pb electrode, Voltammetry cycles. H_2SO_4 were carried out for several times. It was directly used as the negative electrode. As the

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positive electrode, were carried out to form the PbO_4 layer. The counter electrode was a piece of the Pb or PbO_2 electrode cut from the practical battery (Ikeda, S., et al. 2003). Cyclic Voltammetry was carried out in H_2SO_4 solutions using a conventional potentiostat and a function for negative electrodes positive electrodes. Nickel-Cadmium or NiCd batteries will be measured and applied to the voltammetry method using a potentiostat. In this voltammetry measurement, the working electrode uses a 2 x 2 cm nickel sheet and a 2 x 2 cm Cadmium. In order to remove the oxide layer from the Ni electrode, the KOH voltammetry cycle is performed several times. It is directly used as a negative electrode. For a positive electrode, it is performed to form a $Cd(OH)_2$ layer. The counter electrode is a piece of Ni or $Cd(OH)_2$ electrode cut from a practical battery. Cyclic voltammetry is carried out in Electrolytes of Potassium Hydroxide or KOH using conventional potentiostat and function for negative electrode of positive electrode.

Figure 1: Voltammetry cell.

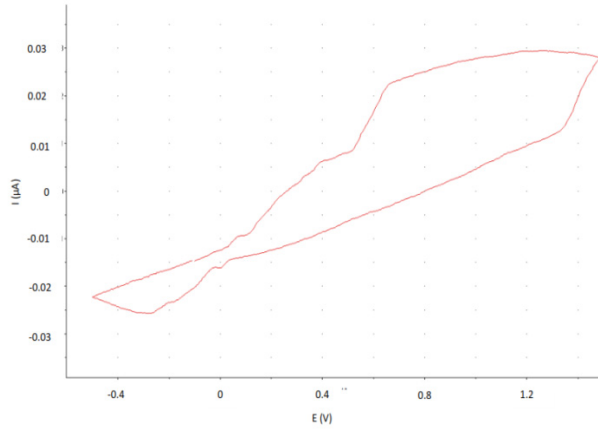
Then, the data of measurement will be applied in to neural network method. Design of the model development lead acid battery based on neural network in this study using current and voltage. So the accuracy testing of the forecasting system using neural network algorithm will be better and more efficient than the experiment data manually.

3 RESULTS AND DISCUSSION

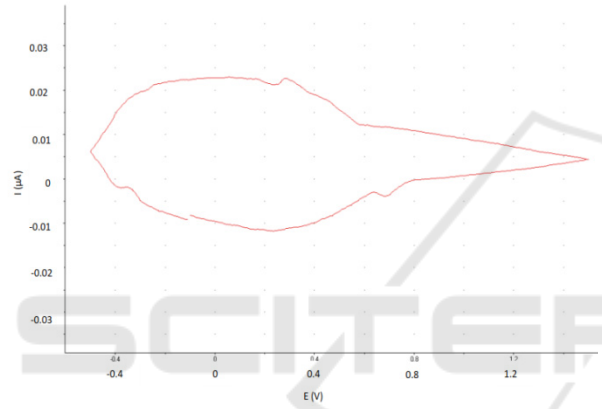
Voltammetry Cyclic is technical analysis used in qualitative analysis of electrochemical reactions. This technique is able to provide information on the oxidation reduction process of thermodynamics and kinetics of electron transfer which occurs on the surface of the electrode. (Kaloko, B. S., et al., 2016), (Kaloko, B. S., et al., 2011). This potential voltammetry in the technique given in a cycle between two values, the potential difference at the start of a potential increase in the maximum and then being down linearly with a slope of the same value back to the initial potential. In this study used Lead Acid batteries or battery lead acid will be tested using the method voltammetry. This battery has two electrodes, namely sized PbO_2 and Pb 2 x 3 cm which serves as the cathode and the anode. In voltammetry there are three independent test electrodes, electrode, electrode pliable, and determinants of the electrode. On testing this using Pb as a working electrode which is the measured electrode, and electrode as a determinant of PbO_2 namely electrodes that have fixed. And for battery nickel cadmium NiCd battery or scars that will be tested using the method voltammetry. This battery has two electrodes, namely and Ni which serves as the cathode and the anode. In voltammetry there are three independent test electrodes, electrode, electrode pliable, and determinants of the electrode. This test using Pb as a work electrode which is measurable, and the Cd as the electrode an electrode which has a fixed value.

Voltammetry cyclic is a technique used to obtain qualitative information about the electrochemical reaction. Voltammetry cyclic is a method to measure the potential waveforms potential electrochemical potential is used in electrochemical analysis is a form of linear waves, the potential continues to change as linear functions at that time. The results of measurements of the cyclic voltammetry can be used to determine the thermodynamic properties of redox processes, kinetic properties of the electron transfer reaction and adsorption reactions (Ikeda, S., et al. 2003).

Voltammetry cell consists of an electrode, an electrode and a reference electrode is a complement, soaked in the cell where the three voltammetry contains the sample solution. Beyond the potential (V) is applied between the electrodes, the working and the reference electrode to produce current. In this study used as the working electrode PbO_2 and Pb in comparison with electrode H_2SO_4 as electrolyte. In this experiment does not use the complementary electrodes because electrode PbO_2 and Pb easily react. So the measurement electrodes PbO_2 and Pb using cyclic voltammetry with the method *potentiostat* shows a graph like Figure 2.



(a)



(b)

Figure 2: Measurement of (a) Lead acid and (b) NiCd with cyclic voltammetry..

After experimenting with using the method voltammetry it will be known to the data flow and voltage which is owned by the battery Of data that has been retrieved is then converted on testing LM-NN or Lavenberg Marquardt Neural Network (Potocnik, P., 2012). By using the neural network toolbox on MATLAB software, artificial neural network structures created as in Figure 2 that has two inputs and one output with two layers. The first layer is hidden layer neurons of fruit with 20 and the second layer is the layer with a single output neuron. On this structure using the input (I) in the form of voltage and battery capacity, while for the target (T) using the results of the multiplication capacity with voltage so that it becomes total energy in batteries. Then on the Neuron, Neurons in this section consists of two parts. The first part is a part of the process of the incorporation of the entire input or inputs from neurons in the image symbolized by the Sigma (∑), then the second part is a part of activation neurons that later in this section information is thrown to the output to be certain information or still thrown into other networks for value input from a network. Mathematically, the workings of the system formulated by the formula (Kusumadewi, S., 2003).

$$in_i = \sum_j W_{ji} \cdot a_j \quad (1)$$

Where in_i is Summation weights and input to the unit i anda_j is value activation of unit j, $w_{j,i}$ is the weights of the units to the unit $i$and j, then g is function activation and a_i is the value of the activation of the unit i as Figure 3.

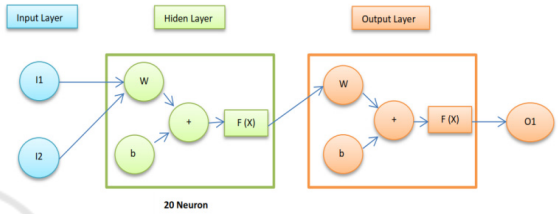


Figure 3: Design of Neural Network Structure.

Where in_i is Summation weights and input to the unit i anda_j is value activation of unit j, $w_{j,i}$ is the weights of the units to the unit $i$and j, then g is function activation and a_i is the value of the activation of the unit i as Figure 3.

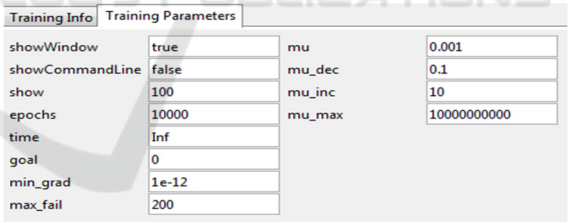


Figure 4: The parameter Traininglm(Training Lavenberg Marquardt) in the lead acid and NiCd battery.

Then do training or training on artificial neural network with the use of trainlm and give the parameters of the Train such as in Figure 3 this function so that the structure of the network become increasingly better at recognizing, saving the dam convey information. Each Training have different results, thus the process of training done repeatedly in order to get the best results.

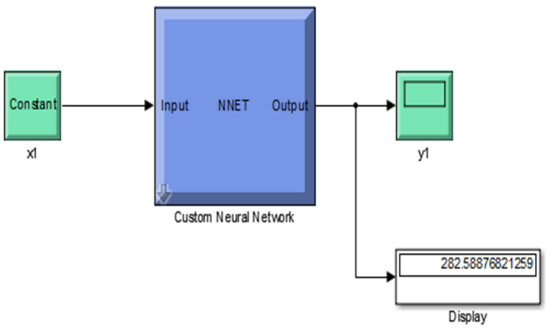
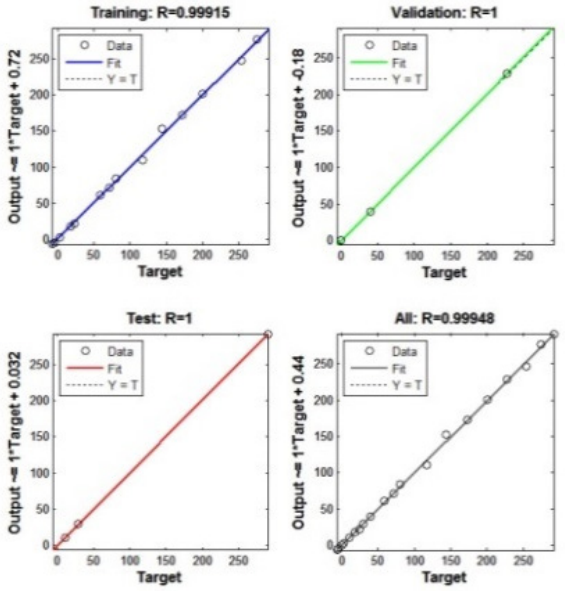


Figure 5: Simulink Diagram NN Lead Acid and NiCd Battery.

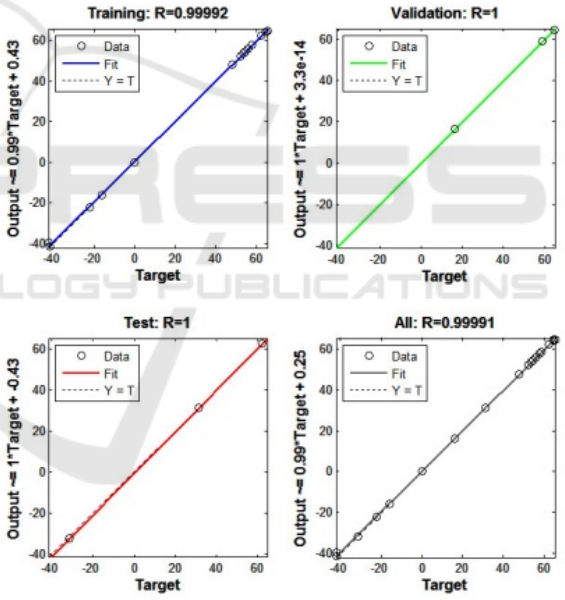
Following the result of the test condition t (time) of 20s and E (voltage) of 1.3 V, with a target of total energy battery is 274.8096 Wh. In Figure 5 shows an output energy of 276.809 Wh. Those values very have approached target with error of 1.9994. This is because the value of the Regression (R) generated during the processing of 0.99915 only training and the level of Validation of 1 as shown Figure 6. The value obtained when the epoch reached 200 iterations within 2 seconds.

The value of Regression determine the correlation between the output and the target. If the value of the Regression approaches 1 as Figure 6, it will indicate the proximity of correlation Regression approach and vice versa if the number 0, then it could be said the output still far from the desired target. Validation is used to measure the network generalization and to stop the process of training. While the epoch is the maximum number of iterations that were made during the process of training.

The value that appears in the output is the result of addition of the multiplication of each input value weights or Weigh. To be able to know the information the weighting of each Dendrite then can be done by opening a section in the block layer 1 or layer 2. In this structure, using a sigmoidal activation function because the function is more easily applied and have good results or close to target. There is a wide range of functions for example, sigmoid activation purelin, ramp, linear, and the step function. After going through the activation of the function, the value of the output of the hidden layer called layer 1 activation value added with value validation at layer 2 or output layer, consisting of the sum of the values of the weights (w) and bias (b) using the sigmoid activation function.



(a)



(b)

Figure 6: Plot Regression (a) Lead Acid Battery and (b) NiCd Battery.

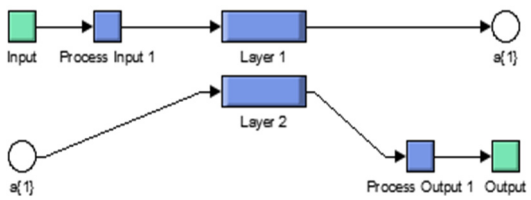


Figure 7: Block Layer 1 and Layer 2 Lead Acid and NiCd Battery.

Table 1:Voltammetry test data results and Neural Network on Lead Acid Battery.

E (Volt)	Voltammetry I(μA)	Capacity (Ah)	Energy (Wh)	Energy NN (Wh)
-0.5	-0.02228	-160.416	80.208	83.656
-0.4	-0.02022	-145.584	58.2336	61.788
-0.3	-0.01829	-131.688	39.5064	39.377
-0.2	-0.01651	-118.872	23.7744	22.011
-0.1	-0.01472	-105.984	10.5984	10.659
0	-0.01240	-89.28	0	0.058
0.1	-0.00928	-66.816	-6.6816	-6.11
0.2	-0.00333	-23.976	-4.7952	-4.822
0.3	0.00148	10.656	3.1968	3.172
0.4	0.00622	44.784	17.9136	18.372
0.5	0.00815	58.68	29.34	29.284
0.6	0.01657	119.304	71.5824	71.442
0.7	0.02328	167.616	117.3312	110.169
0.8	0.02502	180.144	144.1152	152.758
0.9	0.02662	191.664	172.4976	172.575
1	0.02781	200.232	200.232	200.885
1.1	0.02863	206.136	226.7496	228.541
1.2	0.02934	211.248	253.4976	248.676
1.3	0.02936	211.392	274.8096	276.809
1.4	0.02890	208.08	291.312	290.941

From table 1 above by giving potential from the smallest to the largest value produces different currents. On testing voltammetry and neural network value flow reaches the point of maximum 0.02936 μA at the moment given the voltage of 1.3 volts. When testing is done using LM-NN, the resulting output value is not too far from the target or the value of testing voltammetry. With the difference in relative small like that then the error generated is also getting a little bit. As for the calculation of the value of the NN should be equal to the value of output value calculation due to the NN is the value of the calculation of the process of the formation of the value of the output itself from the simulink diagram as in Figure 5.

Table 2: Voltammetry test data results and Neural Network on NiCd Battery.

E (Volt)	Voltammetry I (μA)	Capacity (Ah)	Energy (Wh)	Energy NN (Wh)
-0.5	0.00616	44.352	-22.176	-22.176
-0.4	0.01454	104.688	-41.8752	-41.295
-0.3	0.01954	140.688	-42.2064	-39.902
-0.2	0.02175	156.6	-31.32	-32.076
-0.1	0.02231	160.632	-16.0632	-16.0632
0	0.02261	162.792	0	-1.421
0.1	0.02272	163.584	16.3584	16.3584
0.2	0.02175	156.6	31.32	31.32
0.3	0.02221	159.912	47.9736	47.9736
0.4	0.01894	136.368	54.5472	54.5472
0.5	0.01549	111.528	55.764	55.764
0.6	0.01208	86.976	52.1856	52.1856
0.7	0.01166	83.952	58.7664	58.7664
0.8	0.01086	78.192	62.5536	62.5536
0.9	0.00997	71.784	64.6056	64.6056
1	0.00908	65.376	65.376	64.844
1.1	0.00816	58.752	64.6272	64.336
1.2	0.00721	51.912	62.2944	62,366
1.3	0.00616	44.352	57.6576	57.668
1.4	0.00534	38.448	53.8272	53.8272

The calculation of the value of the lead acid battery capacity that has been through a chemical reaction can be found in the following ways. The number of free charge generated by the active ingredients on the negative electrode and consumed by the positive electrode is called the battery capacity. Capacity is measured in Ah (1 Ah = 3600 C, or Coulomb, where 1 C is the charge transferred in 1 s by 1 A flow on the unit charge MKS). The theoretical capacity of the battery (in C) is where x is the number of moles of the limiting reactants associated with release of the complete battery, n is the number of electrons generated by the reaction to the release of the negative electrode, and $F = Le0$. Then$L$ is the number of molecules or atoms in a mole

(known as Avogadro's constants), and $e_0$is the electron charge. F is the Faraday constants (Kaloko, B. S., et al., 2016), (Kaloko, B. S., et al., 2011)[6]. The values for the constants are$L = 6.022 \times 10^{23}$, $e_0 = 1.601 \times 10^{-19}C$ and $F = 96412.2\ C/mol$ .The calculation of the capacity in Ah:

$$Q_T = 0.278\ F\frac{m_R n}{M_M} \quad (2)$$

Where is the mass of the reactant which mR limit (in kg), and Mm is the molar mass of the limiting reactant (in g/mol). The cells in the battery typically connected in series and the battery capacity is determined by the capacity of the smallest cell. Therefore, $QT = QT$ battery cell. Then discharge rate the current situation where the battery is depleted. The discharge rate is expressed as Q/h rate, where Q is the rated battery capacity, and h is the discharge time in hours. For rechargeable battery has a capacity of QT Ah and are depleted is divided with the formula Q t/T then:

$$T = \frac{QT}{Q/hrate} \quad (3)$$

Lead Acid Battery secondary battery is often used. In the calculation of the lead acid battery capacity battery has a larger capacity than nickel cadmium batteries. In the calculation of the lead acid battery, capacity of 397.993 Ah in one battery and nickel cadmium batteries while the capacity of the battery in Ah one 306.001. Jember Substation had nickel cadmium battery witch the most widely in use as protection systems 84 battery and 40 batteries for SCADA. Then 20 Lead acid batteries just for PLC (Power Line Carrier). In the calculation of the lead acid battery capacity battery has a larger capacity than nickel cadmium batteries. In the calculation, the lead acid battery capacity Ah 397.993 in one of the battery and the battery required battery voltage with as many as 121.358 v. Whereas nickel cadmium battery has a capacity of 306.001 Ah in one and batteries that are needed as much as 8 batteries with voltage V 2.099.

4 CONCLUSION

Results of the two methods yield differences are not far away. From the results of the comparison of simulated neural network with cyclic voltammetry test methods, then there is a difference, and that difference is the error that occurred. If the value of the error is smaller than the resulting data better.

On the battery capacity calculation of lead acid batteries have a larger capacity than nickel cadmium batteries. In the calculation, the lead acid battery capacity Ah 397.993 in one of the battery and the battery required battery voltage with as many as 202.099 V. While the batteries are nickel cadmium has a capacity of 306.001 Ah in one and batteries that are needed as much as 84 battery with voltage 1.358 V.

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