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Original Research Article

Investigation of the Effect of Active Materials of Solar Battery on Active Mass Utilization Co-Efficient

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Abstract

Solar energy is a renewable source of energy. Usage of this energy can reduce the carbon emissions on the environment. To store electric energy produced from solar panels, a battery is used named solar battery. The capacity of storing electricity depends on the active materials of the battery cells. Normally the capacity of a lead acid battery depends on active materials, size of the plates, gravity of the acid, construction of the grid of the plates. In this research, all other variables responsible for battery capacity (gravity of acid, size of the plates, construction of grid etc.) are constant and only one variable is active materials of the plates. 4 batteries containing different amounts of active material are used to identify the best combination which gives the highest value of active mass utilization coefficient.

Keywords: Solar energy, solar panels, battery, plates, gravity of acid.

1. INTRODUCTION

The demand of electricity is increasing day by day. Now in Bangladesh, almost 56% of total electricity has been producing from natural gas. If no new major discoveries of gas fields in near future, the reserve of natural gas will be finished within 10 years [1]. So it will be better to increase the production of electricity using renewable source of energy like solar energy. And also at the time of load shedding we can use solar energy and convert at in to electric energy and used for domestic purpose [2]. So it is very important to find a best device to store the solar energy. And for this lead acid battery is the best device because it is very cheap and it has good capacity density with respect to weight [1]. So it is needed to increase the efficiency of solar lead acid batteries. The efficiency of lead acid batteries mainly depends on area of plate surface, arrangement and porosity of active materials, quantity and strength of electrolyte [4]. In this study condition of operation, quantity and strength of electrolyte, area of plate surface, the grid construction are kept constant for all samples but variation is done in quantity of active materials. So now the capacity of battery will be increased with the increase of active materials of the plate [5]. And the efficiency of active materials will be determined with value of active mass utilization coefficient of the batteries. The ratio of practical capacity to the theoretical capacity is called Active mass utilization coefficient [3].

2. THEORY

A lead acid battery is commonly made of 6 individual cells and the cells are connected in series each cell having 2.1 V nominal cell voltage. The whole battery is of 12.6 V or commonly known as 12 V battery [7].

For a simple demonstration of a lead acid battery requires the following things such as positive Plate with active material, negative plate with active material, electrolyte etc.

Positive and negative plates are made with their individual formulas and dipped into an electrolyte of dilute sulfuric acid. After providing electricity from an external source, a chemical reaction occurs in between the plates and the electrolyte. After removing external source, it acts like a voltage source and can provide huge amount of current for a certain amount of time depending on the size and construction of the battery [4].

At the time of charging the reaction in positive plates and negative plates are stated below [2]:
Positive Plate: $PbSO_4(s) + 2H_2O(l) = PbO_2 + H_2SO_4(aq) + 2H+(aq) + 2e-$
Negative Plate: $PbSO_4(s) + 2H+(aq) + 2e- = Pb(s) + H_2SO_4(aq)$
Overall reaction: $PbSO_4(s) + 2H_2O(l) + PbSO_4(s) = PbO_2(s) + 2H_2SO_4(aq) + Pb(s)$

At the time of discharging the reaction in positive plates and negative plates are stated below [2]:
Positive Plate: $PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- = PbSO_4(s) + 2H_2O(l)$
Negative Plate: $Pb(s) + HSO_4^-(aq) = PbSO_4(s) + H^+(aq) + 2e^-$
Overall reaction: $Pb(s) + PbO_2(s = 2H_2SO_4(aq) + 2PbSO_4(s) + 2H_2O(l)$ + energy

Active mass utilization coefficient is the ratio of actual capacity found from charge-discharge process to the theoretical capacity of positive or negative material. It is denoted by Ƞ [4].
$Ƞ = C_{Actual} / C_{Theoretical}$

Where C_{Actual} is the actual capacity found from constant current discharge process and $C_{Theoretical}$ is the theoretical capacity of positive or negative plate [3].

Electrochemical equivalent weight of active materials of negative plate, G_{NAM}=3.866 g.Pb/Ah
Theoretical capacity, $C_{Theoretical(NAM)} = M_{NAM}/G_{NAM}$

Where M_{NAM} is the mass of active materials of negative plate of Battery [3]

Electrochemical equivalent weight of active materials of positive plate, G_{PAM}=4.463 g.PbO_2/Ah
$C_{Theoretical(PAM)} = M_{PAM}/G_{PAM}$

Where M_{PAM} is the mass of active materials of negative plate of Battery [5].

The Lowest Value of $C_{Theoretical(NAM)}$ and $C_{Theoretical(PAM)}$ is taken as $C_{Theoretical}$ and the actual capacity of battery (C_{Actual}) is found from discharging the battery. After fully charge the battery, a rectifier is used to discharge the battery at constant current up to dropping the 10.5V from 12V and count the discharge time. After that the capacity is measured by multiplying the discharge current with the discharge time. [5].

3. MATERIALS

20 pieces Lead-acid batteries containing same quantity of active materials are used to make one sample. Thus 4 samples containing different combination of active materials are taken. Jinfan rectifier (50A, 415V) is used to run the constant discharge method on the samples. The dimension of positive plate used in every sample is 130mm*150mm*5mm and the dimension of negative plate is 130mm*150mm*2.3mm.

Table 1: Combination of Plates in samples

Sample Type	Type of positive plate	Type of negative plate	Number of Posi-tive plate/cell	Number of Nega-tive plate /cell
Sample 1	ET130T(S)	ET130F(2.3)	2	3
Sample 2	ET130T(S)	ET130F(2.3)	3	4
Sample 3	ET130T(S)	ET130F(2.3)	4	5
Sample 4	ET130T(S)	ET130F(2.3)	5	4

Table 2: Mass of active materials per plate

Sample type	Mass of active material/ positive plate (gm)	Mass of active material / negative plate (gm)
Sample 1	0.168	0.1494
Sample 2	0.168	0.1494
Sample 3	0.168	0.1494
Sample 4	0.168	0.1494

Table 3: Mass of active materials per cell

Sample Type	Mass of active material/ positive cell (gm)	Mass of active material / negative cell (gm)
Sample 1	0.336	0.4482
Sample 2	0.504	0.5976
Sample 3	0.672	0.747
Sample 4	0.84	0.8964

Table 4: Mass of active materials per battery

Sample Type	Mass of active material/ positive cell (gm)	Mass of active material / negative cell (gm)
Sample 1	0.336	0.4482
Sample 2	0.504	0.5976
Sample 3	0.672	0.747
Sample 4	0.84	0.8964

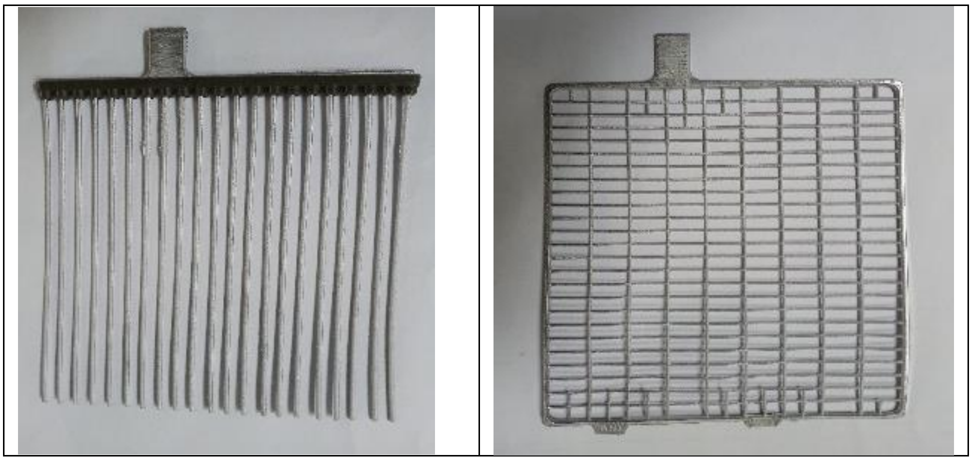


Fig 1: Sample of grids of positive plate and negative plate

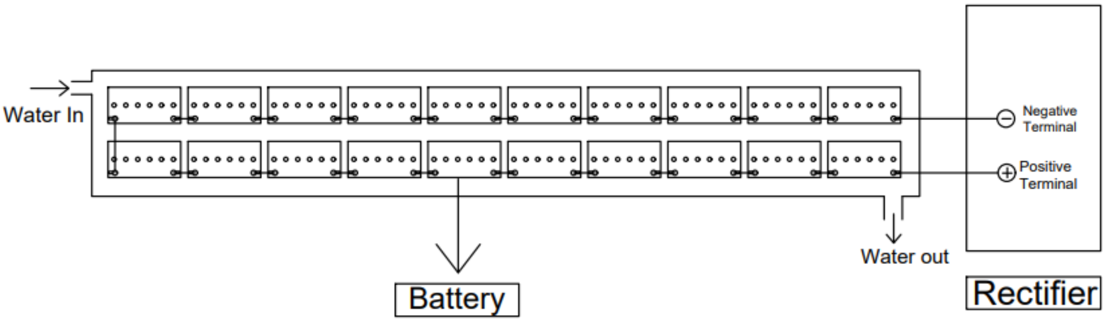
Fig 2: Sample of positive plate and negative plate

2.4% antimonial lead is used to construct the grid of plates. All grids of positive plates are inserted into a set of tubes made of hard synthetic cloth called gauntlet. Then these tubes are filled with a powder mixture of Red oxide, Grey oxide etc. This type of positive plate is called tubular plate. The gauntlet helps to increase the life of the positive plate. After tube filling and strip closing the plates are dipped into dilute sulfuric acid having specific gravity of 1.140 gm/cc. This process transforms the lead oxide into lead sulfate [7]. After completing sulphation process, the tubular plates are washed with DM water at least three times until the pH of water reaches to 7.0. After that positive plates are taken to the drying chamber and dried at 50^0 celsius for 4 hours [3].

Paste of chemicals are made by taking required amount. All flat grid are filled with the paste chemicals in pasting machine. Raw material for the pasting is lead oxide (grey), sulfuric acid, fiber flock, indulin AT, barium sulfate, carbon black etc. After pasting the negative plates, these plates are taken to the curing chamber for curing and drying. For negative plates are cured at 45^0 celsius and 95% humidity. After that cured negative plates are dried at 65^0 celsius. Finally moister of plates is checked. The moister content of negative plate must be less than 1%. So the negative plates are dried unless its moister content is downed up to 1% [2].

3. EXPERIMENTAL SET UP AND PROCEDURE

After completing the preparation of the plates, they are assembled according to the designed combination of negative and positive plates. [5] After that the sample of the batteries are filled with acid of 1.070 gravity and a circuit of 20 batteries are formed by connecting them in a series connection. Then the circuit is connected with rectifier and the charging program are set according to designed procedure. Normally current supply is constant at the time of charging that's why the procedure is called constant current charging method. After finishing the charging processes, the samples are filled with acid of 1.230 gravity. The charging processes are described at the table of 4,5,6,7 [4].




Batteries coneected in series connection


Rectifier

Fig 3: Experimental set up

Then discharge process is started on every circuit to calculate the capacity of the samples. Discharge process is also done at constant current process. The discharged current is fixed and it is 10A for all the samples. Discharge process was continued till the cut-off voltage. The cut-off-voltage was 10.5V for every battery. Every sample has 20 pieces batteries. So cut-off voltage for every sample was fixed at 210V [6]. After fully charged the samples, discharge process was started and continued the process until the voltage of the sample reached to the cut-off voltage. Then the capacity was calculated by multiplying the discharge ampere with the found time from discharge process [8].

Table 5: The program of charging for sample 1

Steps	Condition	Current(A)	Duration(H)
1	Charge	10	22
2	Discharge	4	2
3	Charge	8	16
4	Discharge	4	6
5	Charge	8	22

Table 6: The program of charging for sample 2

Step	Condition	Current(A)	Duration(H)
1	Charge	14	22
2	Discharge	6	2
3	Charge	1	16
4	Discharge	6	6
5	Charge	11	22

Table 7: The program of charging for sample 3

Step	Condition	Current(A)	Duration(H)
1	Charge	20	22
2	Discharge	9	2
3	Charge	16	16
4	Discharge	9	6
5	Charge	16	22

Table 8: The program of charging for sample 4

Step	Condition	Current(A)	Duration(H)
1	Charge	14	22
2	Discharge	6	2
3	Charge	1	16
4	Discharge	6	6
5	Charge	11	22

5. EXPERIMENTAL RESULT AND DISCUSSION

In this research, procedure of plate preparation and charging is same for all samples but only change in active materials and the size of plates. As there is a change in active materials of plates, there must be a variation in the capacity of the samples. And the active material utilization co-efficient of the samples also changes with the changes of size and mass of active materials.

Table 9: Theoretical capacity of the samples

Sample number	Mass of active materials /Cell(g)	Theoretical capacity, $C_{Theoretical}$ (Ah)
Sample 1	336	75.29
Sample 2	504	112.93
Sample 3	672	150.57
Sample 4	840	188.21

Table 10: Actual capacity of the samples

Sample number	Discharge time (H)	Discharge ampere (A)	Cut off voltage/ circuit (V)	Actual capacity (Ah)
Sample 1	3.5	10	210	35
Sample 2	5.42	10	210	54.2
Sample 3	7.67	10	210	76.7
Sample 4	10.33	10	210	103.3

Table 11: Active Material Utilization co-efficient of the samples

Sample number	Theoretical capacity, $C_{Theoretical}$ (Ah)	Actual capacity (Ah)	Activa mass utilization coefficient, ƞ
Sample 1	75.29	35	0.46
Sample 2	112.93	54.2	0.48
Sample 3	150.57	76.7	0.51
Sample 4	188.21	103.3	0.55

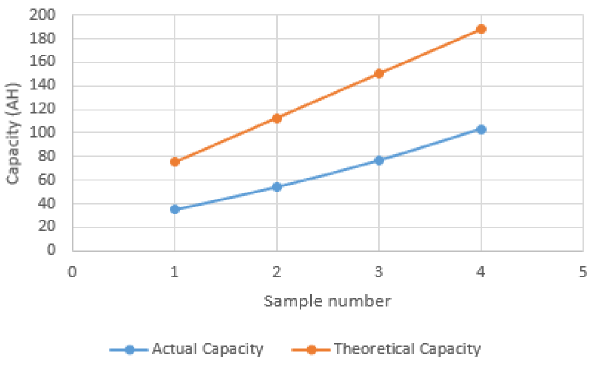


Fig 4: Theoretical capacity and actual capacity of the samples

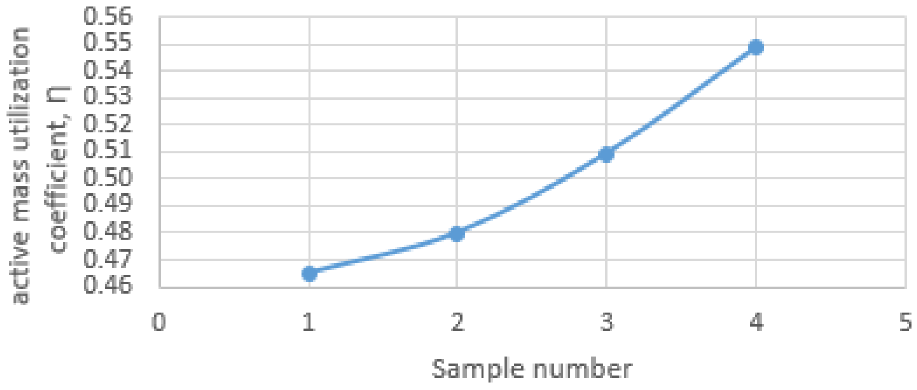


Fig 5: Active mass utilization co-efficient vs sample number graph showing theoretical capacity and actual capacity

From the figure, it is clear that Active mass utilization co-efficient is increased with the increase of active materials at constant current discharge.

7. CONCLUSION

It is clear that if there is no change in the variables (responsible for changing capacity of battery), active mass utilization co-efficient will increase with the increase of the mass of active materials. It is also clarified from the research that active mass utilization co-efficient of lead acid battery is highest for the highest mass of active material. So getting higher active mass utilization co-efficient, it is suggested to use higher mass of active materials and it will be more efficient.

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