

COMPARATIVE STUDY OF WEEKLY DISCHARGE RATE OF TWO SOLAR BATTERIES COMMONLY USED IN ANAMBRA STATE

ABSTRACT

The purpose of this study is to compare the weekly discharge rate of two solar batteries commonly used in Anambra State. The batteries considered were the Indian made battery with specification Luminous, Deep cycle sealed maintenance free batteries solar application, Lum 12V 100Ah 20hr and 3DGP161433 and Chinese made battery with specification Sun-Test std gel battery, 12V-100Ah, 010716w, Cycle use 14.4-15.0V, Stand by use; 13.5-13.8V and Initial current: less than 30A were used to power 2 stand-alone security lights at the Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka. The technical assessment was based on measuring their output voltages bihourly from 19.00hr to 7.00hr and estimation of weekly discharge rate of these batteries for a period of two months (eight weeks). From the analysis, the Indian made solar battery has insignificant discharge tendency for the first eight weeks of its use having its discharge rate of -0.034, -0.038, -0.042, -0.037, -0.039, -0.038, -0.039 and -0.036 Volts/hr per week from week one to week eight respectively whereas the Chinese made solar battery has a relatively high discharge rate of Voltage/hr per week within the first eight weeks of its use having its rate at -0.095, -0.213, -0.103, -0.1, -0.104, -0.1, -0.083 and -0.109 Volt/hr per week from week one to week eight. Also, while the Indian made battery is observed to be relatively stable, the Chinese made battery was observed to be very erratic and highly susceptible to discharge within the first eight weeks (two months) of its use. Hence, it is concluded that Indian made battery is preferred to that of Chinese made battery for optimal performance of stand-alone PV system in Anambra State.

1. Introduction and Background of the study.

Solar energy is the energy from the sun. Solar energy is also the energy produced by the sun in the form of heat and light. It is one of the most renewable and readily available sources of energy on planet earth. The fact that it is available in plenty and free and does not belong to anybody makes it one of the most important of the non conventional sources of energy (<https://www.conserve-energy-future.com>, 2018). According to Iftikhar, *et al.*, (2015), solar energy is derived from the sun and this energy is not only pollution free but also costless. A solar PV system is a system whose function is to generate electricity using sunlight and supply electricity to the load when required (Chetan, 2016). In order to achieve this objective, many components are connected together in solar PV system, other than PV modules. For example, a solar PV module can convert sunlight into electricity. This electricity is available when sunlight is there. But the load may need electricity supply during non sunshine hours. Batteries are mainly used to perform three main functions in PV systems.

- 1. as a buffer store to eliminate the mismatch between the power available from the PV generator and the power demand from the load,**
- 2. as energy reserve device and**
- 3. to prevent large and possibly damaging voltage fluctuations (Nayak,2016).**

Photovoltaic systems have been incorporated with different energy storage devices to increase the overall system performance where battery storage system seems to be paramount (Hon *et al.*, 2016). Some research works focus on the battery sizing while others studied the types of converter suitable for battery applications (Bazargan, *etal*, 2014).

Photovoltaic cells (solar cells) are placed under direct sunlight when the direct sunlight hits these cells; they convert the energy of light directly into electricity (Bhutto *et al.*, 2012). Solar security lights are raised light sources which are powered by photovoltaic panels generally mounted on the lighting structure or integrated in the pole itself. The photovoltaic panels charge a rechargeable battery, which powers a fluorescent or LED lamp during the night. Solar security lights are designed to work

throughout the night. Many can stay lit for more than one night if the sun is not available for a couple of days.

Energy is an important ingredient for the development and economic growth of any country. Energy usage is the key measure of prosperity of the individual, society and thus the nation as a whole. Conventional energy resources are limited with every individual and in every nation. This is depleting at a very fast rate apart from the fact that it is non-clean and is not environmentally friendly. There is a current global need for clean and renewable energy sources. Fossil fuels are non-renewable and require finite resources, which are dwindling because of high cost and environmentally damaging retrieval techniques. So, the need for cheap and obtainable resources is greatly needed. An efficient and more feasible alternative option is solar energy. In stand-alone system that uses solar energy there is need for storage battery and these batteries are expensive and some fail to store energy within months of installation. There is need for comparative study between the available batteries in the market in order to help end users save costs.

2. Materials

The following materials were used for the stand-alone PV security lights located at the Faculty of Physical Sciences Nnamdi Azikiwe University Awka.

- I. Rechargeable batteries: Indian technology with the following specifications;
Luminous Deep cycle sealed maintenance free batteries solar application. Lum 12V 100Ah 20hr, 3DGP161433 and Chinese technology with the specifications;
Sun-Test std gel battery, 12V-100Ah, 010716w, Cycle use 14.4-15.0V, Stand by use; 13.5-13.8V and Initial current: less than 30A
- II. Charge controller
Specification: Voltage - 12/24V, Current – 10A
- III. Dc watt meter
- IV. Cables
- V. LED bulb(20W)
- VI. metal galvanized poles
- VII. Solar panels

Specification:

$V_{OC} - 20V$

$I_{SC} - 5A$

$V_{mp} - 18V$

$I_{mp} - 4.44.$

3. Methodology

Design methodology for Stand-Alone PV Security light.

The design of a solar PV system is about determining the number of ratings of components used in solar PV system to supply reliable electricity to the load which in our own case is the 2 security lights. The design involves calculating the values of different components required to make the complete PV system (namely the PV module, battery, charge controller and the LED bulb) which is capable of supplying electricity to the connected load as required. Here in this study, approximate design methodology was employed (in approximate design, several simplifying assumptions are made with respect to the component performance with referring to the solar radiation data, seasonal variation in the load, performance variation of PV panel with season) since the number of parameters considered here is small and to make the PV system design simple. As compared to the precise design (attention is given to accurate details of all the above factors) parameters, such as amount of solar radiation, temperature variation at the location, and the variation of load according to season are not considered.

Sizing: Sizing is an important part of the design of a stand-alone PV system.

Step1: The connected load and their energy estimation in watt-hour (Wh) was determined.

The load refers to any appliance that needs to be powered by the PV system. Here, the estimation of how much energy required for the operation of the load (LED lamp) was done. Energy consumed by a load in a given day is obtained by simply multiplying its power rating by the number of hours of operation. Thus, the unit of energy would be in watt-hour (Wh). Here, our LED lamp is 20W, therefore,

$$\text{Energy} = \text{Total watts} \times \text{number of hours (Wh)}$$

$$\text{i. e. Energy} = 20W \times 12 \text{ hours} = 240Wh$$

Step 2: The size and choice of the charge controller (the voltage and current of the load and battery) was determined.

The solar charge controller should be chosen as per the required input and output voltage and current of load and battery. The chosen charge controller should be able to handle the currents and voltages that are likely to be flowing in the system.

Here, the nominal system voltage of charge controller was checked: It is usually same as rated voltage of load and PV array which is 12V.

$$\text{Nominal load current} = \frac{\text{Total DC load}}{\text{Nominal System Voltage}}$$

$$\text{Nominal load current} = \frac{20}{12} = 1.666\text{A} \approx 2\text{A}$$

That is the output side, meaning that the charge controller should be able to handle the approximated current.

Step 3: The battery size (their number, capacity, voltage and Ah ratings) was determined.

Here, it is concerned with the number, capacity, voltage and Ah ratings. In battery sizing, several other parameters of batteries have to be considered as well, which include;

- System voltage ampere-hour (Ah) capacity of the battery.
- Depth of discharge (DOD) of battery.
- Number of days of autonomy.

To find the Ah capacity to be supplied, the energy is divided by voltage as,

$$\text{Energy} = W \times h = V \times I \times h$$

$$\text{Ah} = \frac{Wh}{V} = \frac{V \times I \times h}{V}$$

$$\text{Ah} = \frac{240}{12} = 20\text{Ah}$$

The DOD of batteries indicates how much of the total charge of the battery can be used.

In, solar PV, nominally the deep discharge batteries are used with DOD in the range of 50% to 60%. (Chetan, 2016)

The usable charge was estimated if the DOD of battery is given as 50% using

$$\text{Actual capacity (Ah)} = \frac{\text{Ah}}{\text{DOD}\%}$$

$$\text{Actual capacity (Ah)} = \frac{20}{0.5} = 40\text{Ah}$$

The number of days of autonomy was considered: The number of cloudy days for which more energy is to be stored is referred to as “number of days of autonomy. This means that whatever estimation got after considering the DOD, there is need to increase the capacity of the batteries to store extra energy for the number of days of autonomy.

$$\begin{aligned} &\text{Actual Ah capacity after DOD (Ah)} \times \text{number of days autonomy} \\ &= \text{Final required battery capacity (Ah)}. \end{aligned}$$

That is $40 \times 2 = 80\text{Ah}$

100Ah battery was used in the project because that is lowest Ah in the market.

In general, the equation for estimating battery capacity is given as;

$$\text{Total Ah capacity of battery} = \frac{\text{Energy input} \times \text{Number of days of autonomy}}{\text{DOD} \times \text{System Voltage}}$$

$$\text{Total Ah capacity of battery} = \frac{240 \times 2}{0.5 \times 12} = 80\text{Ah}$$

There was no need to get the total number of batteries. Only one battery was used because the load was small.

Step 4: The PV module (panel) size (their number, power rating, Voltage and current ratings).was determined.

Sizing the PV panels: This involves the estimation of daily energy needed to be supplied by PV module and SPV module power.

$$\frac{\text{Total Energy(Wh)}}{\text{Battery Efficiency(80\%)}} = \text{Wh}$$

$$\frac{240}{0.8} = 300\text{Wh}$$

According to Chetan, 2016, the efficiency of lead acid battery is 80%.

PV module sizing then involves estimation of PV module power using equivalent daily sunshine hours.

SPV (solar photovoltaic) module wattage (W) =

$$= \frac{\text{Daily Energy to be supplied SPV module (Wh)}}{\text{Equivalent daily sunshine hours (h)}}$$

$$= \frac{300}{6} = 50\text{Wh}$$

Step 5: The size of wires (in mm) was determined.

The accurate selection of system wiring cables is very essential in order that the system is safe. The wiring must not reduce the performance of any of the components of the systems. The cables in a stand-alone system must be sized correctly to reduce the voltage drops in the cable and to make sure that the safe current handling capacity of the cable is not exceeded.

Hour of usage for the security light = 12hrs (from 19.00hr-7.00hr)

Without battery, the system will only supply power to the load during the day time only and therefore will not solve the fundamental problem that this research seeks to solve.

The battery is sized to cater for energy supply to the loads at night when the sun is not available.

Installation Methodology for the two Stand-alone PV Security lights.

Installation is a process in which the different components are connected in a systematic order to make a perfect working solar PV system to meet predefined demands. Different types and different number of components are used in PV system depending on the requirements. Here, the two stand-alone PV security lights were installed. The stand-alone PV systems as stated before simply mean the self-dependent or autonomous solar PV systems. They do not depend on grid or any other electric power supply that is why they are also called off-grid PV systems. In this research, there were two types of Installations, the mechanical and the electrical. The mechanical involves installing the materials used for mounting our solar panel. The concrete base was laid with the depth of 2.5ft for mounting the galvanized aluminum steel that is 14ft tall. The solar PV module was mounted of the fixed structure pointing to the south direction. The battery cages were constructed for the safe keeping of our batteries. On the other hand, the electrical installation involves connecting the electrical components of the system with the wires. The charge controller used was rated 12/24V with six terminals for battery, panel and load connections. The battery was connected first to enable the charge controller dictate the right voltage configuration. Then the two wires from the panel were connected to the charge controller and the load of 20W LED lamps was also connected to the charge controllers. The first installation was labeled A which contained the 12V Chinese battery while the second installation B contained the Indian battery also. Both were connected to loads of same wattage that is the 20W LED lamps each. The set up was monitored for a period of two months (eight weeks) with the specified readings taken at different intervals.

4. Results and Discussions

The data collected with Dc watt meter were analyzed graphically using Microsoft Excel. The data were collected from 19.00hrs to 7.00hrs of the immediate subsequent day from week one in January to week eight in February of 2017. These 19.00hrs to 7.00hrs of each subsequent day were transformed to 0-12hrs. That is 0, 2, 4, 6, 8, 10 and 12 hours respectively in order to carry out graphical analysis on the data. **The output voltages of Indian made battery and Chinese made battery were recorded for each hour of the day (from 19.00hr-7.00hr) and the average of the output voltages of each of the hours were calculated from the first day to seventh day of each week. That is, at different hours from 0th hour to 12th hour** for each week starting from week one in January to week eight in February, the average of the output voltages were computed for both Indian made battery and Chinese made battery. For the eight weeks of the observation, table 1 shows the average of the output voltage discharge rate of the Indian made battery while table 2 shows the average of the output voltage discharge rate of the Chinese made battery.

WEEK 5 DAYS 29- 35	0	12.9	13	12.97	12.9	12.9	12.8	12.85	12.903
	2	12.84	12.94	12.88	12.84	12.82	12.73	12.78	12.833
February	4	12.75	12.86	12.79	12.78	12.74	12.65	12.71	12.754
STARTS @ DAY 4	6	12.66	12.77	12.72	12.72	12.64	12.56	12.63	12.671
	8	12.6	12.69	12.64	12.62	12.57	12.49	12.54	12.593
	10	12.5	12.6	12.55	12.56	12.48	12.43	12.44	12.509
	12	12.4	12.5	12.45	12.5	12.39	12.36	12.36	12.423
WEEK 6 DAYS 36- 42	0	13	12.97	12.9	12.95	12.85	12.8	12.8	12.896
	2	12.9	12.91	12.82	12.88	12.75	12.74	12.72	12.817
	4	12.84	12.63	12.75	12.81	12.67	12.68	12.64	12.717
	6	12.77	12.73	12.66	12.72	12.61	12.6	12.58	12.667
	8	12.67	12.64	12.58	12.64	12.55	12.53	12.5	12.587
	10	12.59	12.56	12.48	12.56	12.48	12.44	12.43	12.506
	12	12.52	12.47	12.42	12.47	12.4	12.38	12.37	12.433
WEEK 7 DAYS 43- 49	0	12.9	12.84	12.9	12.89	12.9	12.92	12.78	12.876
	2	12.82	12.7	12.82	12.83	12.82	12.84	12.72	12.793
	4	12.73	12.62	12.73	12.77	12.74	12.76	12.64	12.713
	6	12.66	12.54	12.66	12.69	12.66	12.67	12.57	12.636
	8	12.6	12.46	12.58	12.62	12.6	12.59	12.43	12.554
	10	12.51	12.39	12.51	12.55	12.53	12.52	12.36	12.481
	12	12.41	12.33	12.43	12.48	12.46	12.44	12.3	12.407
WEEK 8 DAYS 49- 56	0	12.8	12.92	12.94	12.9	12.87	12.8	12.9	12.876
	2	12.73	12.84	12.86	12.84	12.8	12.73	12.83	12.804
	4	12.66	12.77	12.78	12.77	12.73	12.65	12.77	12.733
	6	12.58	12.7	12.71	12.69	12.65	12.59	12.69	12.659
	8	12.51	12.62	12.62	12.62	12.58	12.52	12.63	12.586
	10	12.42	12.53	12.52	12.53	12.51	12.44	12.54	12.499
	12	12.35	12.45	12.45	12.46	12.41	12.36	12.48	12.423

Careful observation of table 1 shows that the output voltage discharge rate for the Indian made battery is relatively very low from 0th hr to 12th hr from week1 in January

to the eight week in February. Apart from the very low discharge rate of the Indian made battery, the Indian made battery never tripped off throughout the period of the observation.

Table 2: The output voltage of Chinese made battery with time

WEEK 1 DAYS 1-7	HOUR	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	Average output voltage
19.00 HRS	0	12.56	12.55	12.47	12.44	12.22	12.02	12.52	12.397
January	2	12.37	12.36	12.27	12.34	12.02	11.82	12.48	12.237
	4	12.17	12.16	11.97	12.14	11.83	11.62	11.92	11.973
	6	11.87	11.86	11.78	11.84	11.64	11.52	11.72	11.747
	8	11.77	11.76	11.58	11.74	11.54	11.42	11.52	11.619
	10	11.47	11.57	11.48	11.64	11.43	11.32	11.42	11.476
07.00HRS	12	Tripped off	11.43	11.41	11.45	11.32	Tripped off	Tripped off	6.516
WEEK 2 DAYS 8-14	0	12.35	12.39	12.44	12.55	12.49	12.38	12	12.371
	2	12.15	12.09	12.25	12.35	12.29	12.19	11.81	12.161
	4	11.95	11.89	11.95	12.19	12.09	11.99	11.61	11.953
	6	11.7	11.69	11.89	11.87	11.89	11.79	11.41	11.749
	8	11.5	11.49	11.69	11.97	11.69	11.59	11.31	11.606
	10	11.3	Tripped off	11.44	11.65	11.49	11.29	11.11	9.754
	12	Tripped off	Tripped off	11.25	11.52	11.29	Tripped off	11.01	6.439
WEEK 3 DAYS 15- 21	0	12.48	12.74	12.9	12	12.7	12.54	12.56	12.560
	2	12.28	12.7	12.71	12.2	12.5	12.34	12.38	12.444
	4	12.09	12.5	12.51	12	12.25	12.15	12.18	12.240
	6	11.75	12.26	12.21	11.75	11.95	11.95	11.93	11.971
	8	11.7	11.9	12.01	11.55	11.75	11.7	11.74	11.764
	10	11.5	11.8	11.81	11.45	11.55	11.5	11.54	11.593
	12	11.3	11.5	11.51	11.25	11.35	11.3	11.34	11.364
WEEK 4 DAYS 22- 28	0	12.57	12.58	12.37	12.09	12.08	12.15	12.8	12.377
	2	12.37	12.38	12.27	11.89	11.98	11.95	12.6	12.206
	4	12.18	12.08	12.07	11.79	11.79	11.7	12.54	12.021
	6	11.88	11.89	11.88	11.54	11.61	11.5	12.1	11.771
	8	11.68	11.69	11.68	11.34	11.41	11.34	11.96	11.586

	10	11.48	11.49	11.33	Tripped off	11.31	Tripped off	11.9	8.216
	12	11.29	Tripped off	Tripped off	Tripped off	Tripped off	Tripped off	11.55	3.263
WEEK 5 DAYS 29-35	0	12.9	12.5	12.4	12.7	12.7	12.97	12.94	12.730
	2	12.7	12.31	12.2	12.56	12.86	12.71	12.84	12.597
February	4	12.4	12.11	12.01	12.36	12.61	12.47	12.64	12.371
STARTS @ DAY 4	6	12.21	11.81	11.71	12.19	12.26	12.28	12.34	12.114
	8	11.91	11.71	11.51	11.8	12.11	12.08	12.24	11.909
	10	11.71	11.61	11.31	11.7	11.65	11.98	12.14	11.729
	12	11.41	11.41	Tripped off	11.47	11.45	11.91	11.95	9.943
WEEK 6 DAYS 36-42	0	12.72	12.52	12.75	12.7	12.79	12.94	12.65	12.724
	2	12.52	12.32	12.54	12.65	12.59	12.75	12.45	12.546
	4	12.33	12.26	12.34	12.45	12.39	12.55	12.07	12.341
	6	12.41	12.12	12.09	12.2	12.19	12.39	11.87	12.181
	8	12.04	12.02	11.83	12	11.99	11.94	11.6	11.917
	10	11.93	11.92	11.63	11.8	11.79	11.75	11.35	11.739
	12	11.82	11.72	11.3	11.6	11.59	11.35	11.35	11.533
WEEK 7 DAYS 43-49	0	12.74	12.8	12.5	12.28	12.58	12.2	12.05	12.450
	2	12.55	12.6	12.31	12.58	12.38	11.82	11.85	12.299
	4	12.34	12.35	12.11	12.38	12.16	11.62	11.65	12.087
	6	12.34	12.15	11.91	12.07	11.83	11.42	11.45	11.881
	8	11.83	11.91	11.81	11.92	11.65	Tripped off	Tripped off	11.824
	10	11.63	11.71	11.61	11.68	11.43	Tripped off	Tripped off	11.612
	12	11.43	11.51	11.51	11.48	Tripped off	Tripped off	Tripped off	6.561
WEEK 8 DAYS 50-56	0	12.4	12.56	12.57	12.58	12	12.59	12.08	12.397
	2	12.2	12.36	12.52	12.37	11.81	12.39	11.88	12.219
	4	11.9	12.11	12.12	12.12	11.61	12.2	11.68	11.963
	6	11.7	11.81	11.82	11.82	11.41	11.9	11.48	11.706

	8	11.4	11.61	11.62	11.62	Tripped off	11.7	Tripped off	11.563
	10	Tripped off	11.42	11.42	11.42	Tripped off	11.51	Tripped off	6.539
	12	Tripped off	Tripped off	Tripped off	Tripped off	Tripped off	11.31	Tripped off	1.616

For Chinese made battery, the output voltages were not steady, but observed to be erratic. From the first week of the study (Table 2), the Chinese made battery was observed to have started tripping off at 12th hour of the daily observations. This characteristic of tripping off continued to be on the increase with the Chinese made battery for the rest of the weeks, the tripping off took place at earlier hours such as 12th, 10th and 8th hours.

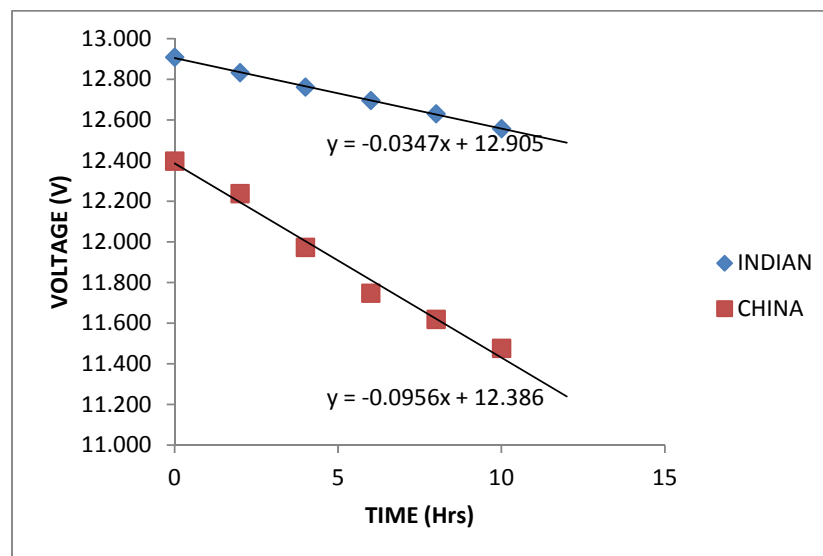


Fig. 1. Graph of average output voltage against time in week one for Indian made battery and Chinese made battery.

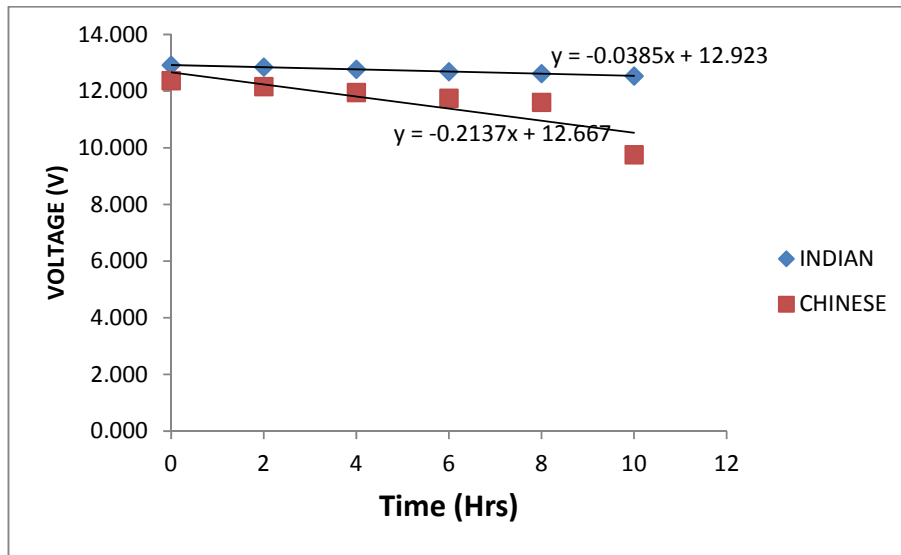


Fig.2. Graph of average output voltage against time in week two for Indian made battery and Chinese made battery.

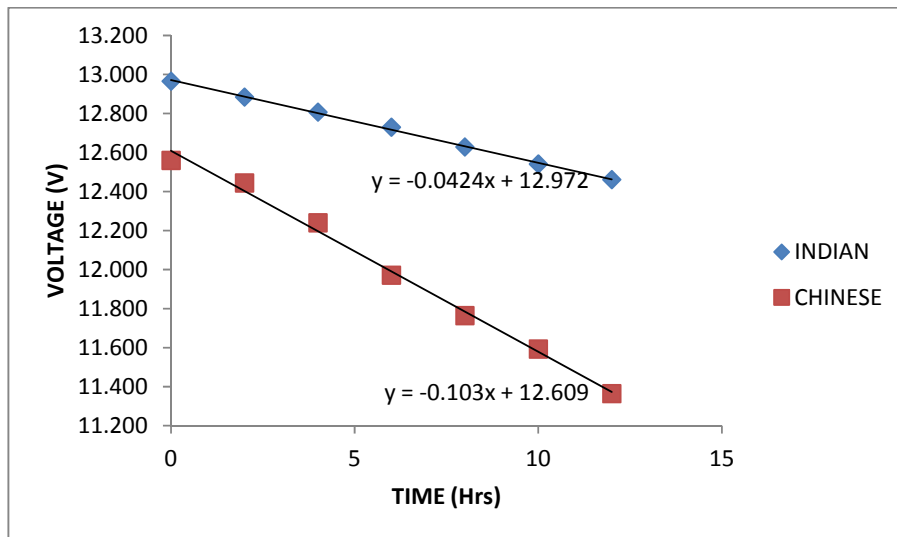


Fig. 3. Graph of average output voltage against time in week three for Indian made battery and Chinese made battery.

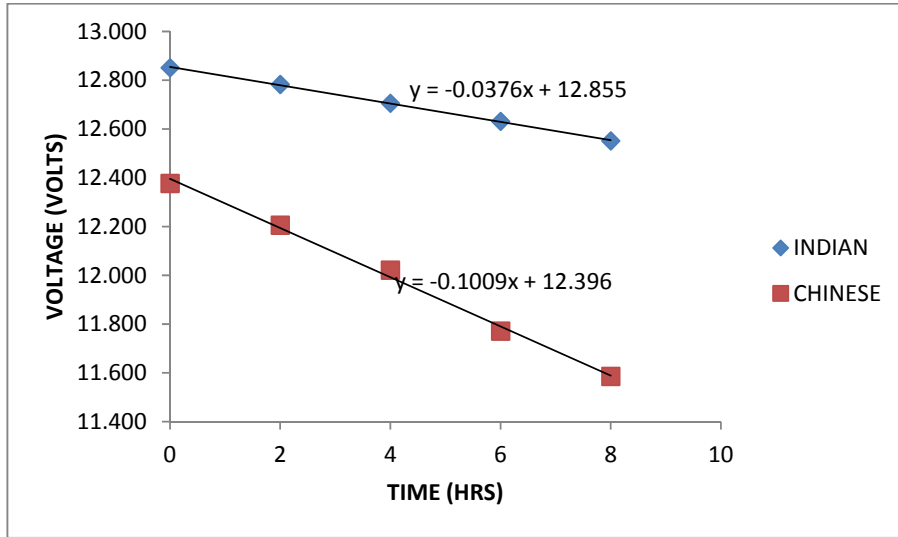


Fig.4. Graph of average output voltage against time in week four for Indian made battery and Chinese made battery.

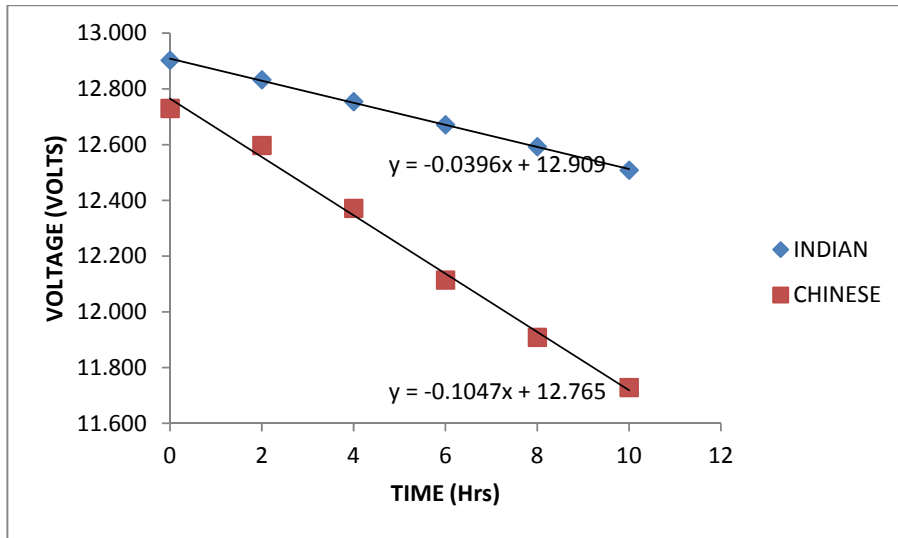


Fig. 5. Graph of average output voltage against time in week five for Indian made battery and Chinese made battery.

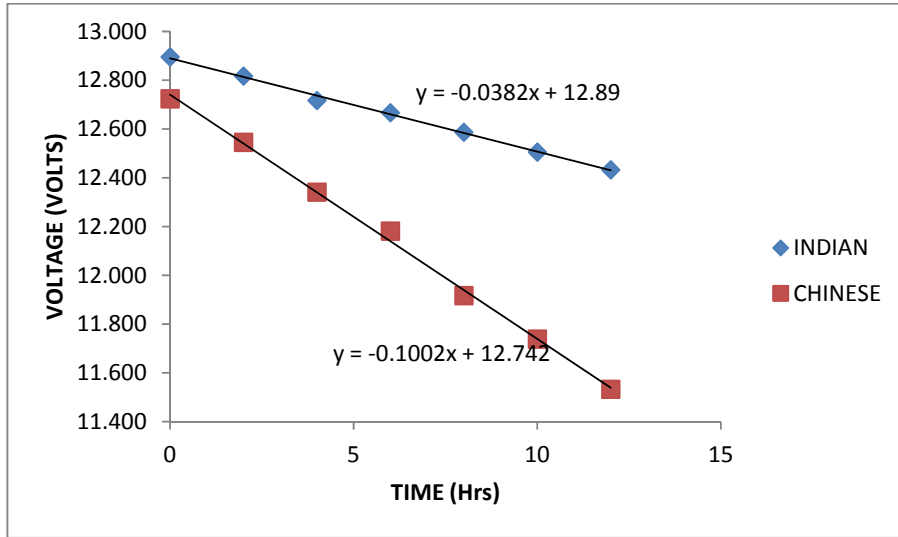


Fig. 6. Graph of average output voltage against time in week six for Indian made battery and Chinese made battery.

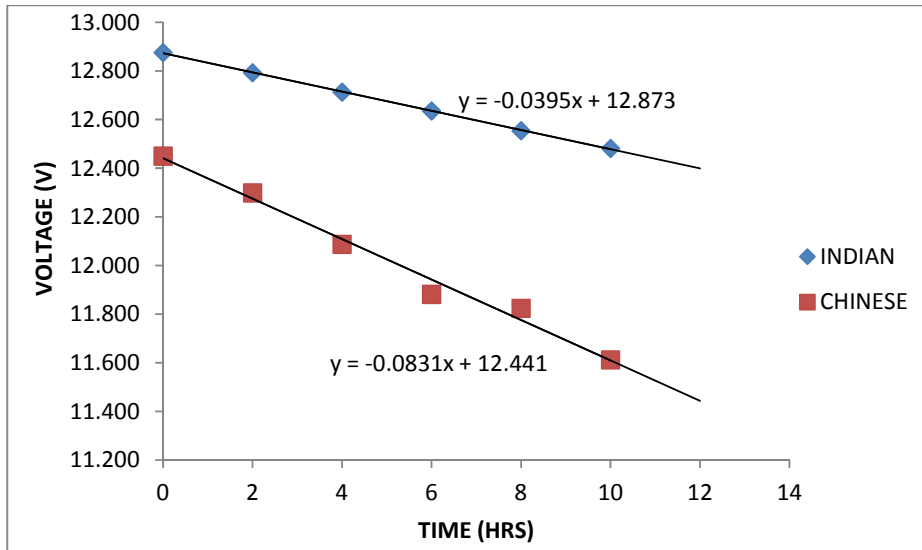


Fig. 7. Graph of average output voltage against time in week seven for Indian made battery and Chinese made battery.

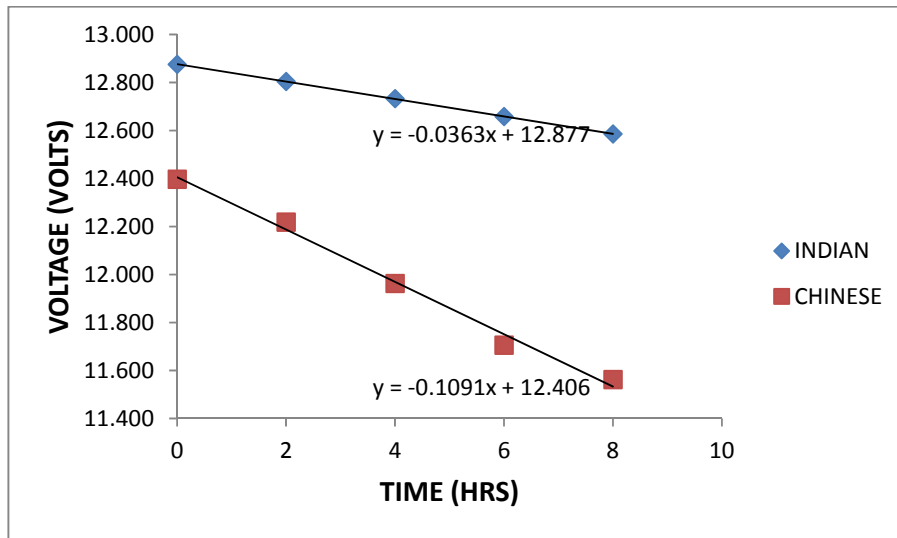


Fig. 8. Graph of average output voltage against time in week eight for Indian made battery and Chinese made battery.

For each of the figures 1 to 8, the equation of the lines of best fit for both Indian and the Chinese series were computed. The equation shows that for each of the weeks the discharge rate of the Indian battery is significantly low ie -0.034, -0.038, -0.042, -0.037, -0.039, -0.038, -0.039 and -0.036 Volts/hr per week from week one to week eight respectively whereas the Chinese made solar battery has a relatively high discharge rate of Voltage/hr per week within the first eight weeks of its use having its rate at -0.095, -0.213, -0.103, -0.1, -0.104, -0.1, -0.083 and -0.109Volt/hr per week from week one to week eight.

6. CONCLUSIONS

Based on the relevant steps taken on the foregoing research, the following conclusions are hereby drawn. Both the Indian and Chinese made solar batteries are usable in Anambra State metropolitan. **In the first two months of the year, the Indian made Solar battery has insignificant discharge tendency of -0.034, -0.038, -0.042, -0.037, -0.039, -0.038, -0.039 and -0.036 Volts/hr per week from week one to week eight respectively and the Chinese made Solar battery has significant discharge tendency of -0.095, -0.213, -0.103, -0.1, -0.104, -0.1, -0.083 and -0.109Volt/hr per week from week one to week eight. while in use. The erratic performance which characterizes the Chinese made battery is most likely owing to its poor charging capacity thereby completely off in some of its days of use hence the Indian made battery is preferable.**

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