



Battery Charger Efficiency and Voltage Behaviour in Vented Lead Acid Batteries in Kenya

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Abstract

Electricity despite being critical is limited to few people in developing countries. This has encouraged the use of battery based systems with unknown efficiencies. Field experimental performance of industrial and Jua Kali battery charger is thus given. The result of voltage recorded during charging shows that there were significant differences ($t = 4.775$, $df = 1$, $P = 0.0000$) in the voltage of batteries charged for both chargers. During discharge it was noted that the batteries charged by the industrial and Jua Kali chargers although having same capacities of 12V, 32 AH took about 70 and 30 minutes respectively to fully discharge to a terminal voltage of 10.5v. This revealed that batteries charged by the Jua Kali charger had acquired less charge due to its weak charging mechanism. It is imperative that such charger be redesigned for better charge delivery.

Keywords: Electricity; voltage; battery; battery charger

1. Introduction

Energy has been described as the 'missing' Millennium Development Goal, the catalyst without which other goals on issues such as health, education and gender equality cannot be achieved. Studies show that access to modern energy services, and particularly electricity, has a positive effect on local economic development and closely correlates to a country's UN Human Development Index [1].

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African countries just like other developing nations are characterised by low access and insufficient supply of electricity. Some 24% of the population of sub-Saharan Africa has access to electricity versus 40% in other low income countries. Excluding South Africa, the entire installed generation capacity of sub-Saharan Africa is only 28 Gigawatts, equivalent to that of Argentina [2]. Voltage fluctuations coupled with poor reliability as a result of power outages averaging 56 days per year have driven cost of production to unimaginable level [3]. Capable firms have thus invested in their own generating capacities just like in many parts of South Asia, increasing cost of production by 2 to 3 times [4].

Power tariffs in most parts of the developing world fall in the range of US\$0.04 to US\$0.08 per kilowatt-hour [2]. However, a case study of eastern Africa shows a huge disparity in tariff ranging between US\$ 0.037 in Burundi to US\$ 0.2374 in Uganda per kWh of social tariff consumption [5]. Electricity consumption per capita is also at worrying level where, 54% of the countries have an average consumption of below 200kWh/capita, with only 18% having an average consumption of over 1000 kWh/capita [6]. Kenya and Nigeria, the so called eastern and west Africa economic giants have an electricity per capita consumption of 155 and 149kWh respectively against that of Egypt and South Africa which stands at 1743 and 4604 kWh [7].

As a result of the gap in service delivery in power supply, Small Scale Private Service Providers are financing, developing, and managing the delivery of small scale services to their client base which includes battery charging stations to solar home systems and isolated mini power grids [8]. In Kenya the most common power supply for off-grid electricity is 12 volt batteries. The market is largely over-the-counter. The majority of people tend to use their batteries to generate electricity for television, music, phone charging, and light (prioritized in that order). There are probably more than one million Battery Based Systems (BBS) in use in Kenya. Most consumers recharge BBS in urban battery charging stations at a cost between US\$ 0.50 – 1.00 per charge. As many as two thirds of these systems charge batteries through battery chargers connected to the grid [9].

Within Kenya, there exist two different charger types, that is the industrial chargers manufactured by regulated formal industries, and the Jua Kali chargers manufactured by the unregulated informal manufactures. The latter, lacks simple ratings that are always found in product name plates hence it is difficult knowing its charging ability. It has also been noted that 7% of such services reported some type of accident experienced by customers who include; minor electric shocks, explosions and burns caused by hot battery acid [8]. This does not only reduce the live of batteries being charged, but also deprives the end user the right to quality and quantity of electricity supplied. It is with respect to this that a comparative study of the two charger types is given in order to bench mark the performance of informal charger against that of industrial charger in terms of charge received by batteries during charging and the amount of charge supplied by batteries during discharge.

2. Objective

The objective of the study was to determine the efficiency of battery charger types on batteries voltage variations during charging and discharge cycle.

3. Methodology

The study constituted an experimental design conducted on two different types of battery chargers namely; industrial and Jua Kali lead acid battery chargers. Ten battery charging stations were studied for each type of charger. The charge transferred to the batteries acted as treatments to the batteries receiving charge. The industrial charger was set as a control. In each battery charging station five different types of vented lead acid batteries were studied. Time during charging was recorded on one hour time interval, while during discharge, a ten minute time interval was used.

In determining the capacity of charged batteries, accumulators were discharged using a constant resistive load draining 25A. Discharge was stopped when the terminal open circuit voltage was 1.75V/cell [10]. Those batteries charged by industrial chargers were coded as Chloride Exide1, KV1, 3K1, AP1, and Dynagrid1, while those charged by the Jua Kali chargers were Chloride Exide2, KV2, 3K2, AP2, and Dynagrid2. The batteries used were expected not to be older than 3 months since the date of purchase when new and were all rated at the same capacity of 12volt, 32 AH. Batteries KV1 and KV2 were brand new batteries, hence acted as controls on batteries charged by the two charger types [11].

The student t-test and one way ANOVA was used to analyze if there existed a significant voltage difference in batteries charged by the both the industrial charger and the Jua kali charger. The level of significance was taken at $\alpha=0.05$. Univariate data analysis permitted for clear understanding of trends with respect to the test of significance obtained.

4. Results and discussion

4.1 Battery charging

The objective of the study was to determine the efficiency of charger type on the accumulators' voltage variations during charging and discharge cycle. The result of voltage of the accumulator during charging is shown in Figure 1. There were significant differences ($t = 4.775$, $df = 1$, $P = 0.0000$) in the voltage of batteries charged using industrial chargers and Jua kali chargers. Batteries charged with industrial chargers had higher mean voltage than those charged with the Jua Kali chargers. This was attributed to low battery impedance in batteries charged by industrial charger. Such batteries allowed flow of higher charging current unlike those charged by the Jua Kali charger. This relates to earlier studies done by [12], where it is argued that as current from the battery moves through the cell, the cell's voltage changes because of its internal cell resistance. When the cell is being recharged, current flow causes the cell's voltage to rise. The higher the charging current; the higher the voltage. [13] Further points out that the internal impedance of a cell determines its current carrying capability. A low internal resistance allows high currents.

Results showing the differences in the voltage of the different battery types during the battery charging with industrial chargers as compared to those charged with Jua Kali chargers are as shown in Table 1. There were no significant differences in voltage of the individual batteries during the battery charging process using industrial chargers ($F = 0.424$, $df = 4$, $P = 0.791$). Likewise, individual battery voltages charged with Jua Kali chargers did

not display any significant differences ($F = 1.390$, $df = 4$, $P = 0.237$). This matches with battery charging standards given by [14] where it is indicate that any battery-industry standards ensure that any off-the-shelf battery charger, specified for one brand, size, and type of battery, should be able to charge correctly any brand of battery of that same size and type. However, the individual batteries charged with industrial chargers were all having higher open circuit voltage ($P < 0.05$) than batteries charged with Jua Kali chargers.

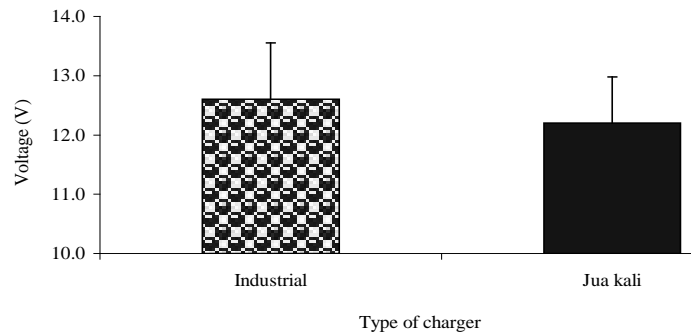


Figure 1. Mean voltage (V) of the batteries charged by the two battery charger types

Table 1. Mean voltage (V) of different battery types during battery charging

Battery type	Industrial	Jua Kali
Chloride exide	12.59 ± 0.11 ^b	12.40 ± 0.10 ^a
KV	12.68 ± 0.12 ^b	12.18 ± 0.11 ^a
3K	12.58 ± 0.13 ^b	12.14 ± 0.11 ^a
AP	12.69 ± 0.12 ^b	12.12 ± 0.09 ^a
Dynagrid	12.49 ± 0.15 ^b	12.15 ± 0.08 ^a

Mean values followed by different superscript down the column are significantly different at $\alpha = 0.05$. The superscript “a” and “b” denotes the standard errors resulting from deviations about the mean.

Trends in voltage changes in the batteries during charging using industrial and Jua kali chargers are indicated in Figure 2. From the graph, battery voltage of both industrially charged batteries and Jua kali charged batteries consistently increased with duration of charging. However, the rate of increase in voltage of the batteries charged by the industrial chargers was higher than the rate of voltage increase in the batteries charged by Jua Kali chargers. This is consistent with earlier studies done by [15] where it is argued that during battery charging voltage rises to a predefined value before switching to trickle charge.

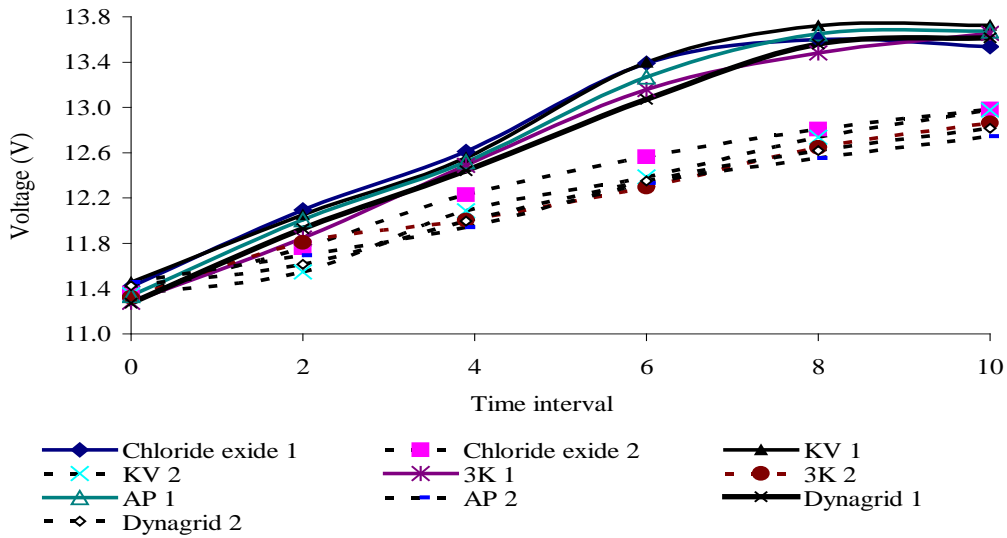


Figure 2: Trends in voltage (V) changes during battery charging

4.2 capacity test

The results of voltage in batteries discharged after charging with two charger types are shown in Figure 3. There were significant differences ($t = 7.119, df = 1, P = 0.0001$) in the voltage between the batteries discharged after charging using industrial chargers and Jua Kali chargers. Batteries discharged after charging with industrial chargers had higher mean voltage than those charged by the Jua Kali chargers. This was as a result of high IR within the batteries charged by the Jua Kali charger as compared to low IR developed within batteries charged by the industrial charger. This conforms to earlier studies done by [16] in which it is stated that when current flows through the cell there is an IR voltage drop across the internal resistance of the cell. This decreases the terminal voltage of the cell during discharge thus reducing its effective capacity as well as decreasing its charge/discharge efficiency. It further states that higher discharge rates give rise to higher internal voltage drops due to increased internal impedance. Hence, the batteries charged by the industrial chargers stored higher charge resulting into more mean voltage values than those of batteries charged with the Jua Kali chargers which had lower mean voltage values.

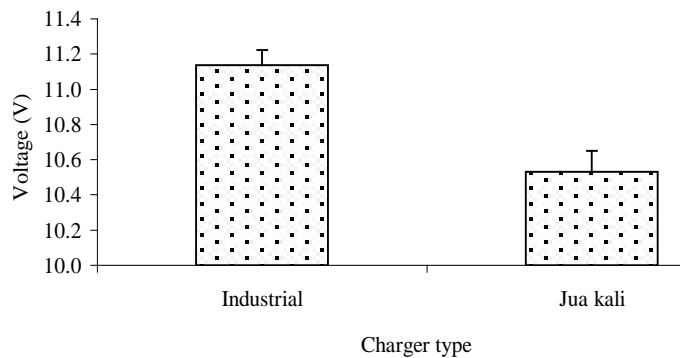


Figure 3. Mean voltage (V) of batteries during battery discharge after charging with the two types of chargers

Results showing the voltage of the accumulator during battery discharge after charging using the two types of battery chargers are shown in Table 2. There were no significant differences in the voltage of the accumulators among the individual battery types charged by industrial chargers

($F = 0.460$, $df = 4$, $P = 0.765$). Individual accumulator voltages for batteries discharged after charging with Jua kali chargers did not exhibit any significant differences ($F = 0.356$, $df = 4$, $P = 0.840$). However, the individual batteries discharged after charging with industrial chargers all had higher voltages ($P < 0.05$) than batteries charged by the Jua Kali chargers. This is supported by earlier studies done by [14] as the batteries charged were of the same capacity and thus behaved same way when subjected to same discharge load.

Table 2. Mean voltage (V) of different battery types during battery discharge

Battery type	Industrial	Jua kali
Chloride oxide	11.03 ± 0.13^b	10.41 ± 0.27^a
KV	11.07 ± 0.13^b	10.42 ± 0.24^a
3K	11.15 ± 0.12^b	10.54 ± 0.20^a
AP	11.18 ± 0.11^b	10.62 ± 0.17^a
Dynagrid	11.24 ± 0.11^b	10.67 ± 0.17^a

Mean values followed by different superscript down the column are significantly different at $\alpha = 0.05$. The superscript “a” and “b” denotes the standard errors resulting from deviations about the mean.

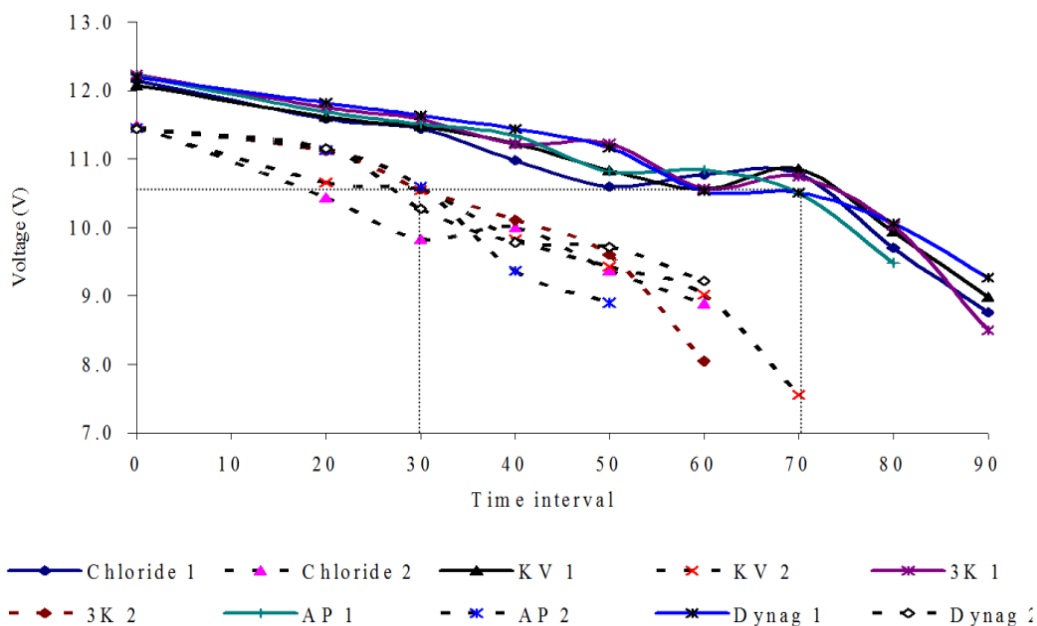


Figure 4. Trends in voltage (V) changes during battery discharge after charging with the two types of battery chargers

Trends in voltage changes in the batteries during discharge after charging using industrial and Jua Kali chargers are indicated in Figure 4. From the graph, trends in voltage changes during discharge using the two types of battery chargers indicated that voltage of the batteries during discharge significantly reduced. However, the rate of decrease in the voltage was higher in Jua Kali charged batteries than industrially charged batteries. The trend conforms to studies done by [17], where it is noted that battery capacity is dependent on discharge current, temperature and final cut-off voltage. However, the rate of decrease in the voltage was higher in industrially charged batteries than Jua Kali charged batteries. This was attributed to higher charge in batteries charged by the industrial chargers as compared to batteries charged by the Jua Kali chargers.

5. Conclusion

Replenishing battery with the right amount of charge is essential in sustaining the lives of the poor who are fully dependent on such service in developing countries. A well charged battery does not only prolong its use per charge, but also increases the number of charge and discharge cycles during its entire operational period. This is economical as it gives the consumer more electricity with low running cost. In this study however, Jua Kali battery charged batteries was found to have acquired less than half the amount of charge acquired by industrially charged batteries. Therefore there is need to rework the charging mechanism of the Jua Kali battery for better efficiency.

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