Towards Optimal Utilization of Deep Cycle Battery

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ABSTRACT

Deep Cycle Batteries (DCBs) in renewable energy systems are designed to regularly discharge most of its capacity. This gives the advantage of long lasting energy supply for electric power backup but they undergo a variety of discharge patterns and performance characteristics due to variation of different manufacturing process and components used for design of different products/makes of DCBs, their temperature of operation , state of charge, depth of discharge and their application. In this research work, we propose to benchmark varieties of DCBs that would be readily available focusing on their depth of discharge patterns in order to obtain a balance between performance, optimum operating condition, mode of operation and cost of these batteries. The concept of this research work is presented in this paper as a foundation for this research, this paper also describes the design methodology and preliminary development of this research work. The result obtained from the benchmarking would be analyzed with a statistical package for social science (SPSS) and a model will be developed. The findings of this research will be uploaded on a well-designed web base system for researchers, individuals, companies and the manufactures of these batteries as they are not manufactured in tropical regions.

Key words: Depth of discharge (DOD), state of charge (SOC), battery capacity, inverter **,** benchmarking

1. Background of the study

Deep cycle batteries are the key component in various types of renewable energy system that requires the storage of electricity. It is a critical component heavily relied upon by the system as a whole. A battery bank can provide a relatively constant source of power when the grid is down, or during periods when your photovoltaic system is not producing power. The inconsistency in electric power supply in countries around the world has brought about an increase in the use of electric power backup system. (www. Wholesalesolar.com/solar-information/deep-cycle-battery-info)

The deep cycle battery was invented by the French physician Gaston Plante` in 1859, deep cycle battery was the first rechargeable battery for commercial use. Early models were flooded and during the mid-1970s the sealed or maintainers free versions emerged in which the liquid electrolyte is transformed into moistened separator and the assembly is placed in a sealed enclosure. Safety valves control the venting of the gas as generated during charge and discharge.

This modified version of the standard cell may be used to improve storage times and reduce maintence requirements. Gel-cells and absorbed glass-mat batteries are common in the roles, collectively known as VRLA (valve-regulated lead-acid) batteries. These batteries are good backup for electric power in some countries.

Due to the instability and unreliability of electric power supply in Nigeria, individuals and companies are compared to seek to other alternative source of electric power supply or backup systems like use of generators, inverters, solar energy, wind energy, geothermal and deep cycle battery. The use of deep cycle batteries for energy backup is increasingly gaining ground due to its cheap cost, maintance and reliability as a result there is a large influx of deep cycle batteries from different manufacturers in the Nigeria market where power supply outages are a common phenomenon.(Apeh S.T et al 2013)

To ensure stability and power quality, renewable energy is often compensated with storage unit. The LABs (DCB type) is by far, the most common storge method for these applications since it is well-studied science and can provide sustained power over extended period of time and is designed to be repeatedly charged and recharged using most of its capacity.

Unlike many other battery applications, battery-based renewable energy applications are unique because the batteries in these systems can be discharged and charged in an unpredictable manner due to variations in sunshine, wind, inverters and hydro power. They are also subjected to seasonal variations that can result in the battery having to operate in a partial state of charge for considerable length of time. These factors can cause the batteries to result in frequent deep discharges and lack of charge. Consequently, the most important requirement for batteries used in renewable energy systems is long cycle life.

However, the performance of DCBs varies from one manufacturer to another irrespective of the similar classification and stated ratings due to difference in their production processes and components used for their design which may result in varying internal resistance of the batteries. This varying internal resistance can affect the performance of this batteries, also the temperature of operation these batteries causes a variation in their performance. This research work would benchmark varieties of DCBs that were readily available focusing on their depth of discharge patterns in order to obtain a balance between performance, optimum operating condition, mode of operation and cost of these batteries.

2. STATEMENT OF PROBLEM

Battery performance deteriorates over time whether the battery is used or not. it is however common to find users complaining about the performance of their batteries in terms of the discharge rate, charging rate and the operating temperature of these batteries as compared with the specifications giving by the manufacturers of these batteries. Abusive applications of the batteries shorten their life spans and the user's end up not deriving optimum performance from their use.
(S.T. Apeh,et al.,2013).

Although this batteries are used in the tropical region like Nigeria for electrical power backup, there have been no test done to check the optimal charactertics of these batteries as compared to the manufactures specification, hence the need to benchmark different batteries commonly used to obtain a balance between performance, optimum operating condition, mode of operation and cost of these batteries. A web resource base system will be design to house all information obtained from the analysis

3. MOTIVATION AND KEY OBJECTIVES

- ❖ The aim of this study is to design a web resources base for optimal deep cycle battery utilization in the tropics. The specific objectives of this study are;
- ❖ To benchmark the different batteries commonly used (same rating).
- ❖ To determine the effect of stress factor and ageing mechanisms on the deep cycle battery.
- ❖ To determine the optimum temperature for deep cycle battery operation.
- ❖ To determine the quality and best mode of operations of deep cycle battery. V. To create a web base system to house the result obtained after the analysis. VI. To validate the benchmark data generated

3.1 Relevance of the Study

The inconsistency in electric power supply in countries around the world has brought about an increase in the use of electric power backup system. The use of deep cycle batteries (DCBs) has become one of the most common systems in Nigeria. Since these batteries are not manufactured here in the tropical regions,there is need to study these batteries in order to obtain a balance between performance, optimum operating condition, mode of operation and cost of these batteries .

3.2 Related work

Several authors and researchers have investigated different DCBs in different locations, with different products and operating regimes, but each researcher has used his/her own method of analysis, focused on a specific topic of interest, and based their findings on the data that were available to them. The following are some researchers;

Apeh S. T. et al., (2013) developed a management system for maximizing DCBs, the system was designed using a microcontroller based on 50% DOD detector with supply cutoff and an Analog-to-Digital converter. The aim of the design was to design and develop a device that is capable of detecting the DOD of DCBs and cutting of power supply from the battery terminals to the inverter when the DOD becomes equal to or less than 50%. The test showed that the system is capable of detecting 50% DOD for DCBs and turning the battery supply off. The drawback of this study is that the rate of discharge of the batteries was not actually considered and no benchmarking operation was carried out on the batteries.

Henrico et al., (2005) did a research on lifetime modeling of DCBs, under the benchmarking project work two different battery life calculation methodologies were investigated and further developed. The first is based on a cycle counting approach similar to that used in structural fatigue analysis; the other is based on the application of across matrix, developed by the project for linking a number of stress factors with the recognized DCB damage/ageing mechanism. The aim of the study was to improve the prediction of the life of batteries in hybrid power systems and to examine the inter correlation between the major stress factor and ageing mechanisms that affect the batteries. The result of the model simulations correctly ranked the lifetime of the batteries with respect to the expected outcome of the profiles.it also shows that all DCBs will suffer from the same damage mechanism but to different degrees and that the stress factors are as a result of the characteristics features of the battery operating condition which alter the rate of action of the mechanism. The drawback of this study is that the impact of battery temperature was not fully integrated in any of the test exercise and no actual test on battery conditions, as simulations was majorly carried out.

Baring –Gould E.I., et al (2005) did a research Energy Power System Consumption (A summary of the European Union Hybrid Power System Component Benchmarking Project). In this benchmarking research, two methodologies were implemented (1) cycle counting- this tests emphasized on the DOD and SOC event of the batteries. (2) Weighted Ah model-this emphasized on the voltage of the batteries during charging and discharging. The aim of the study was to improve the design of renewable based hybrid power systems based on the analysis of the existing systems and the benchmarking of specific system components, most critically batteries in order to create categories of renewable energy supply that are characterized by similar conditions of use for the component (batteries) under investigation. The result of the model shows a good prediction as well as the weighted Ah- model. The drawback of this study shows that no actual test on battery conditions, as simulations was majorly carried out.

In the current research, different batteries will be physically benchmarked against each other under similar conditions and temperature with individual inverter of the same type and rating (100VA, 12V) will be used for the benchmarking process.

4. METHODOLOGY

4.1 The Research Design

The methodology of this research work is experimental base but firstly, a questionnaire will be designed, distributed and analyzed using SPSS to obtain the commonly used batteries which will be included among the batteries that will be used for the experiment.

Materials that would be used for the experiment includes;

10 deep cycle batteries of same rating but from different manufacturer

10 inverter of the same rating and manufacturer

A data logging circuit will be designed to collect and house data obtained from the experiment at regular intervals.

Soma battery load tester (BLT)

Digital multimeter

Connecting cables

4.2 Uses of Major Equipment

1. **The Inverter –** This is an electronic device that changes direct current (DC) to alternating current (AC). It converts the chemical energy stored in the batteries into electrical energy and runs from the rechargeable battery. It is also used in charging the batteries. A 12V inverter is used in this work, because the batteries to be used will also be rated 12V.

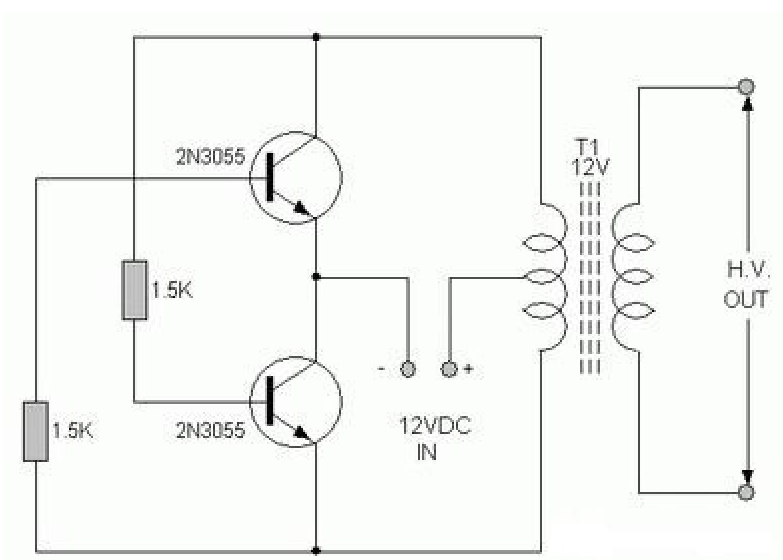

Fig 4.1: Basic circuit of an inverter

2. **The Battery Load Tester (BLT)–**It is a device used to check the condition of LABs. The ten batteries used for this research work will be tested with the BLT before undergoing analysis. The BLT is used on a DCB as shown in fig 5.2.

Fig 4.2: the BLT in use.

3. **Pliers and Spanner –**They will be used to hold, tighten and loosen bolts and nuts at the battery terminals.
4. **Search light –**They will serve as the load to the batteries during the experiment.
5. **Connecting Cables –** These are the wires used to connect the DCBs to the inverter. Red and black colours of cable will be used in order to ease differentiation between positive and negative connections.
6. **The temperature Environment –**The benchmarking experiment will be done for a period of one year so as to work across the temperature conditions of the tropical seasons.
7. **The data logging circuit** – This circuit, built around embedded technology, would be used to collect data from the different sensors in experimental setup at regular intervals to enhance consistency and precision in the timing of data collection.
8. **Batteries –** This is the main component for the research work. Deep cycle batteries are the common means of energy storage used in renewable based rural energy systems

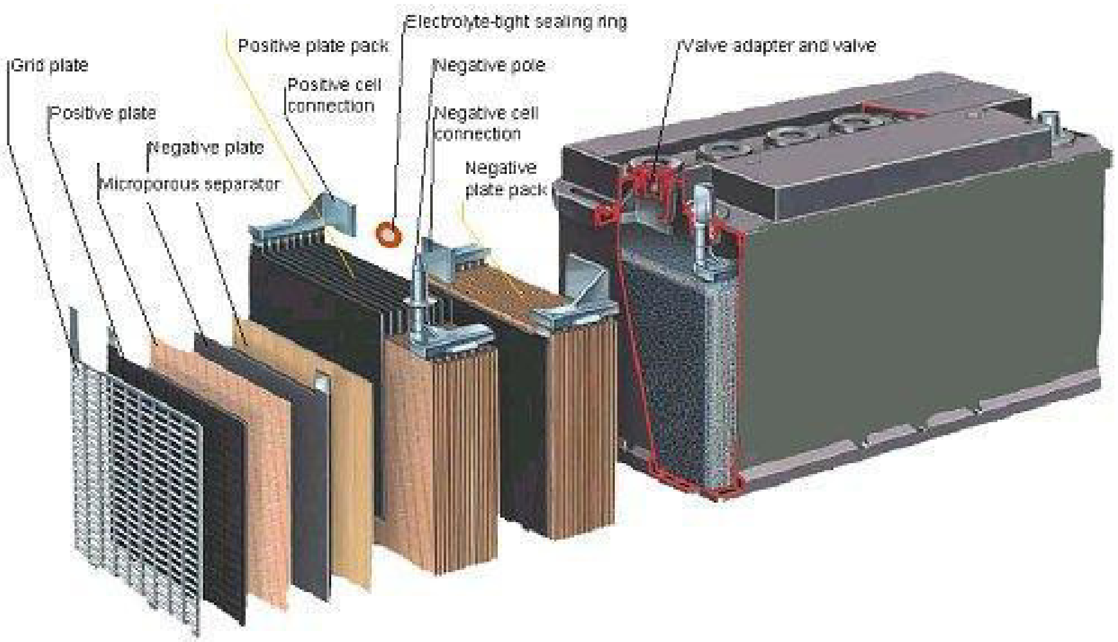

Fig 4.3: Schematic/internal structure of a DCB

4.3 The Benchmarking Process.

Benchmarking can also be referred to as a system by which organizations or units can measure their position and performance level by comparing the performance of similar processes to other corporations or units. *(John Nikiletats and Stachis Tselepis ,2008)*

Therefore, benchmarking can generally be referred to as a learning process to finding better ways of doing things. (*Ifeoluwa Ajolabi and Yinshang Tang,2010)*

The definition of benchmarking reveals that benchmarking is not only a measurement process that results in comparative performance measure, it also describes how exceptional performance is attained.

The model of benchmarking process is famously referred to as the "Deming cycle" and it includes a minimum of four phases "Plan –Do-Action-Check" as illustrated by (*Ifeoluwa Ajolabi and Yinshang Tang,2010)* in Figure 4.4.

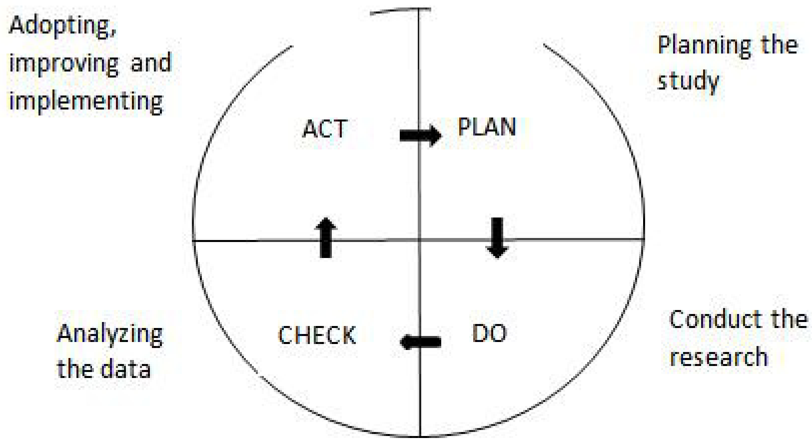

Fig 4.4: Deming Benchmarking cycle

In the course of this proposed research, Benchmarking is stream-lined as a process in which DCBs from different manufacturers and of different designs are compared using identical test conditions. Here 10 batteries with ratings 100AH, 12V would be benchmarked against each other under similar conditions and temperature with individual inverter of the same type and rating (100VA, 12V) will be used for the benchmarking process. Data on the rate of discharge of the battery will be generated over a period of one year, under varying weather conditions as temperature plays an important role in the performance evaluation. The data obtained from the depth of discharge and other conditions like the rate of discharge and charge capacity will be used as reference for the analysis of the different batteries. To reduce the error in the collection of data from the anaylsis, a data logging system would be designed to collect the data of the stated conditions from the benchmarking process. This data collected would be analyzed using SPSS and a model will be developed which will be validated and compared with existing models.

5. PRELIMINARY ASSUMPTIONS BEFORE THE BENCHMARKING PROCESS

i The ten DCBs would be charged to full capacity with the inverter; test with the BLT and then allowed to float to about 13.22v
ii The output voltage of the inverter would be at 220-240VAC
iii The voltage taken across the battery terminals immediately a load is applied is taken as its 100% charge state.
iv Voltage readings are would be taken every 30mins until the battery completely discharges to about 10.5V.

6. DATA PRESENTATION

The results would be obtained base on voltage across the battery terminals for the different parameters to be measured, which would be taken at 30mins interval of time with the applied load. The result obtained from the benchmarking process would be housed in this format for the different batteries

Table 1: Format for Benchmark Result

Displayed voltage (v) level	**Time**	**State of charge (SOC) %**	**Depth of discharge (DOD) %**	**Voltage per cell**
0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00

The following calculations would be made;

1) Calculations for state of charge;

Depth of discharge is the opposite of state of charge, therefore the state of charge will be given as

100% - %SOC = % DOD

Therefore,

100% - % DOD = % SOC

2) Calculation for the vplts per cell;

Since a 12v DCB is madeup of six individual cells, therefore the volt per cell will be given as, v/6 , where v = displayed voltage level.

7. CONCLUDING REMARKS

This proposed research is expected to determine optimal performance characteristics of deep cycle batteries (DCBs) for maximum utilization value by running some experiment on these batteries. With this, it will be able to determine which particular battery performed better under what conditions.

The result of this proposed study will be uploaded on a well-designed web base system for researchers, individuals, companies and any person of interestoin these batteries on their operational performance characteristics for the tropical regions.

8. FUTURE WORK

There are several different directions that future work in this area can continue. Firstly, further research could be done on DCBs, in order to determine the average number of cycles in which DCBs that are liable to increasing performance with cycle attain before a decline in their performance Secondly a model/relationship for adequately determining the exact runtime of DCBs with varying loads should be established.

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