Factory Test of a TP-100 Lithium-Ion Vision Battery System for Possible Implementation in Soweto, Johannesburg, South Africa

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ABSTRACT

Until recently, lead-acid batteries were the go-to source for storing energy for UPS/Inverter applications. The most common types of batteries used in wind applications are Valve-Regulated Lead-Acid batteries (VLRAs). But, lead-acid batteries have drawbacks that make them risky and expensive to use in wind turbine applications. They are the element that is most likely to fail at the moment when they are most needed. It is hard enough to deploy and manage lead-acid batteries traditionally. But when VRLAs are used in remote facilities, there are some problems that increase the effort and the cost of using them. Currently, the Soweto Small Wind Turbine is incorporated with the Vertiv (Inverter) and VRLA battery type. TP 100 Vision lithium iron phosphate (LiFePO4) batteries offer substantial advantages. This battery system is ideal for both UPS/Inverters and energy storage systems, offering excellent compatibility and a secure, durable lifespan. Factory testing was carried out on the installation and testing of a TP 100 Vision battery to a Vertiv-type UPS at a South African company. A variable resistive load bank was added to the UPS output in order to test and evaluate the outcome. This paper presents the factory testing results and proposes the implementation of the TP100 Vision battery to a 500W Small Wind Turbine (SWT) in Soweto, Johannesburg, South Africa.

Keywords-TP 100 Vision battery; factory test; Soweto SWT implementation

I. INTRODUCTION

In South Africa, the main energy source is electricity produced by fossil fuels such as oil and coal. Reliance on these energy sources continues to severely limit the national electricity production. The total wind power potential of South Africa is estimated to be 6,7000GW and is found to be competitive with the solar potential [1]. Moreover, the use of fossil fuels in the generation of electricity contributes significantly to Greenhouse Gas (GHG) emissions, which contribute to climate change [2, 3]. According to [4], utilizing renewable energy as an alternative energy source will reduce environmental problems, essentially GHG emissions and air pollution. Storage of energy is an important factor in wind turbine use. These batteries store the generated energy from the turbine, and the stored energy is sent through an electronic regulator to the inverter for output supply. A battery storage system is regarded as an indispensable component in numerous applications. There are two battery types suitable for wind turbine application, Valve-Regulated Lead-Acid (VRLA) and Lithium-Ion batteries (Table I).

The utilization of sustainable batteries for energy storage is highly recommended in order to safeguard the environment from impeding emissions [5]. Additionally, the investigation conducted in [6] presents evidence that lithium batteries utilizing $LiFePO_4$ technology possess eco-friendly characteristics and are capable of being entirely recycled. The Li-Ion battery technology is relatively recent in its inception [7-11]. Lithium ion batteries have been gaining increasing recognition as a reliable choice for back-up power systems and UPSs/Inverters, primarily due to their exceptional properties such as heightened safety measures and greater energy densities both in gravimetric and volumetric terms. Therefore, a preliminary review on recent developments of Li-Ion batteries acting as battery storage systems on wind turbine application will be discussed below. Two Li-Ion batteries with 400kW output power and 744kWh energy capacity with an 800kW wind turbine, connected to the grid, near in Regina, Saskatchewan, North America were studied in [12]. The wind-battery system's data were continuously monitored to evaluate the performance and to assess the reliability and durability of the storage system. The aim was to quantify the battery effectiveness and assessing peak energy dispatching times. The data showed that there was 65% ramp rate reduction and 400kW dispatching for 90 minutes 3 times per day.

TABLE I. CHARACTERISTICS OF VRLA AND LITHIUM-ION BATTERIES

VRLA	**Lithium-Ion Vision**
Unreliable performance	Reliable performance
Short life	Long life
Requires huge area for installation	Can fit in any space - compact space
They are heavy and difficult to move	They can be easily accessed and are not heavy to move
Temperature sensitive	Accommodates higher temperature
Slow recharge	Fast recharge

According to the U.S. Department of Energy's Global Energy Storage Database, there were 102 Li-Ion battery installations worldwide in operation or in development in March 2014, with an estimated combined storage of more than 175MWh [13]. Authors in [14] proposed the use of Li-Ion batteries as a backup power of the pitch system of wind turbines. The battery management system was designed based on DSP28335. By the use of CAN communication and voltage current Hall sensors, the system realized the collection of cell voltage, total voltage, and charge and discharge currents parameters of the batteries. Ampere-time integration and other methods were used to estimate the battery State of Charge (SOC) when they charged or discharged. During the charging and discharging period, the data of the ICA were recorded. Finally, the function of battery management system was verified by experiments.

Uninterruptible power supply (UPS) systems are of significant importance as contingency and emergency power solutions for vital applications, including but not limited to computers, medical and life support systems, communication systems, office equipment, hospital instrumentation, industrial controls, and integrated data centers. In instances of failure, UPS systems offer dependable, unwavering voltage and frequency power [15].

In this article, the implementation of the TP100 Vision Lithium Battery system integrated to a Vertiv type UPS is studied. The battery system was optimally implemented and tested at one of the companies in Johannesburg, South Africa. The tests results which were performed can greatly benefit the consideration of integrating the TP-100 Vision battery system to a wind turbine installation in Soweto.

II. PRODUCT OVERVIEW AND CHOSEN METHODOLOGY

A. TP100 Vision Lithium Battery

Figure 1 depicts a 50Ah - TP100 Vision Lithium battery module. Table II shows the features of a Vision Lithium battery. The module has BMU units that monitor voltage and temperature to control temperature and balance battery cells, improving efficiency and cycle life. Moreover, the module is filled inside with sheet metal shell for safety and reliability also designed for stable and secure battery cluster integration.

Fig. 1. TP100 51.2 Vdc at 50Ah Vision Li-Ion battery module.

TABLE II. 50Ah – VISION LI-ION BATTERY FEATURES

Feature	Value
Voltage and block capacity	51.2Vdc at 50Ah
Cell type	Lithium ion Phosphate (Life PO_4)
Cell dimensions	130 × 36.5 × 162mm
Weight	1.42kg
Nominal cell voltage	3.2V/cell
Minimum cell voltage	2.8V/cell
Max cell voltage	3.65V/cell
Operating Temperature	0 – 45°C

B. Cabinet Battery Monitoring System (CBMS)

Figure 2 shows an overview of the CBMS. The CBMS cabinet has three levels of architecture, namely battery current detection, alarms and protection, and data analysis and communication. The BMS cabinet includes the control switch circuit, the main circuit breaker, a detection circuit, power supply, processing circuit, starting circuit, chassis, and wiring. Moreover, it manages the state and protects against overcharging and short circuits.

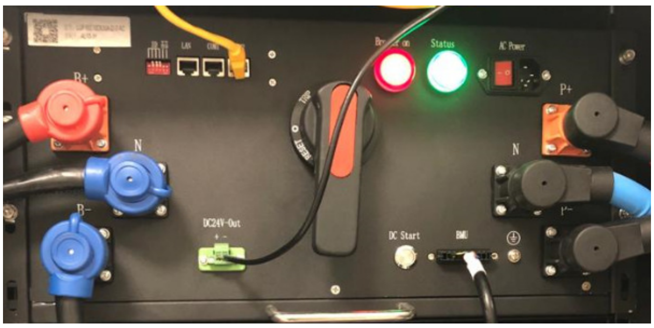

Fig. 2. CBMS view.

Fig. 3. GBMS view.

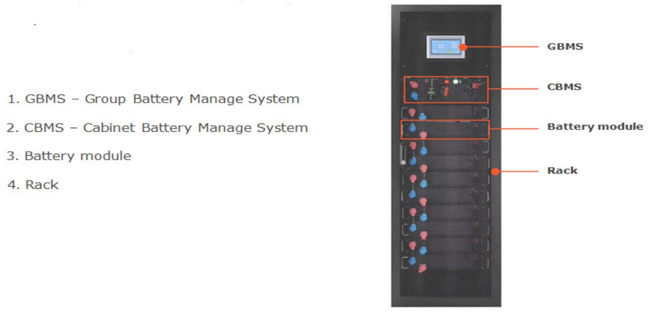

Fig. 4. 50Ah – BMS cabinet with GBMS, CBMS, and battery module.

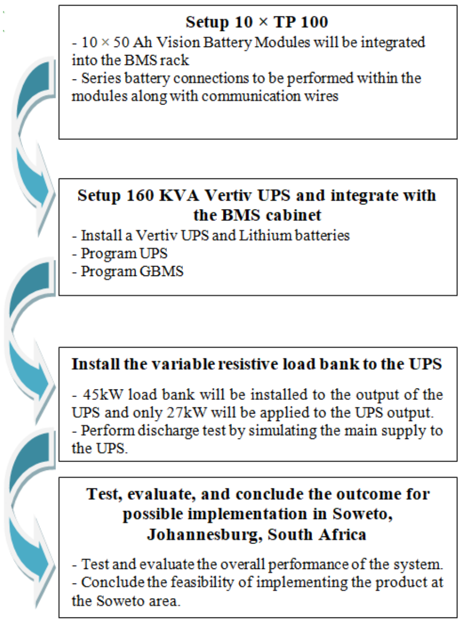

Fig. 5. The followed methodology.

Figure 3 depicts an overview of the GBMS, which contains the lithium battery with an integrated display. It is responsible for collecting and processing data from the CBMS. The Group Battery Manage System (GBMS) displays the CBMS status in real-time at control cabinet level. It works with UPS/Inverter, using multiple connections to maintain system safety and reliability. Figure 4 shows a complete setup of the BMS Cabinet, with CBMS, GBMS and integrated Battery Module. The block diagram of the followed methodology can be seen in Figure 5.

C. Setup, Installation, and Evaluation

A BMS cabinet packed with 10×50Ah Vision battery power modules was connected and configured to a Vertiv type UPS. Figure 5 shows the setup and operation with 45kW dummy load installed, but with only 27kW applied to the output of the UPS. Discharge test was performed to test the Vision batteries with a stop watch timer set on. GBMS was used to monitor every battery module and temperature within the BMS cabinet as shown in Figure 6. Figures 7-11 show the GBMS view during testing in Johannesburg.

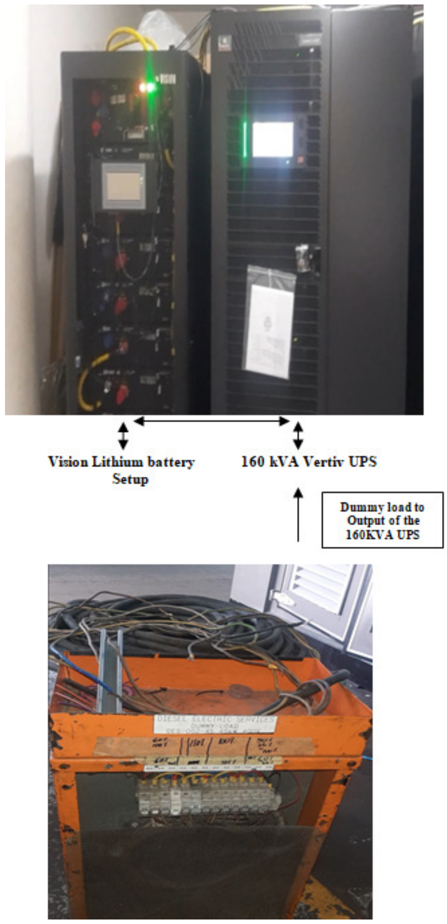

Fig. 6. Setup and operation of UPS and the vision battery system.

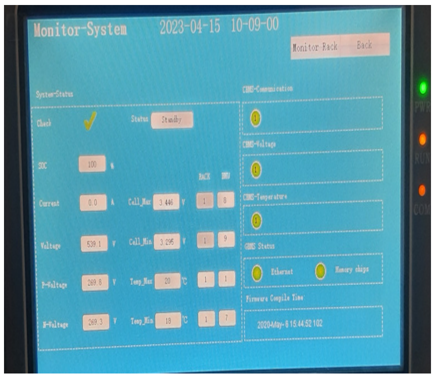

Fig. 7. GBMS monitoring system during testing (1).

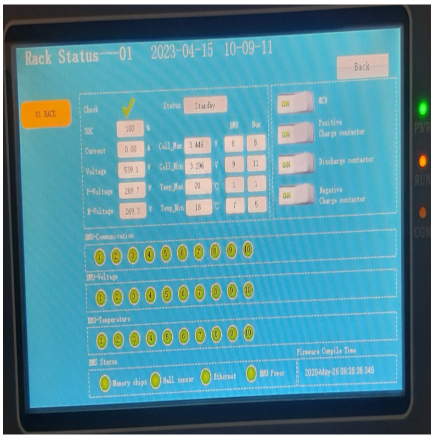

Fig. 8. GBMS monitoring system during testing (2).

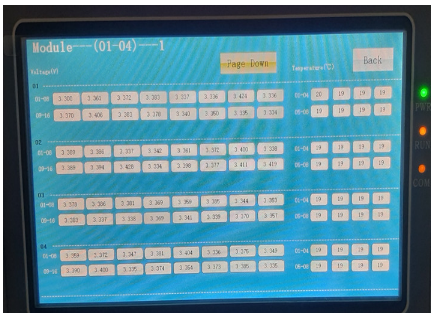

Fig. 9. GBMS monitoring system during testing (3).

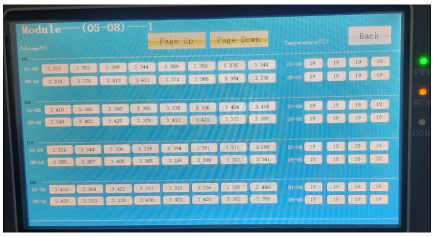

Fig. 10. GBMS monitoring system during testing (4).

III. RESULTS AND DISCUSSION

With 45kW load installed and only 27kW applied to the UPS output, during battery discharge, the results showed that the Vision Lithium battery system was reliable as a storage system. Figures 11-16 depict the readings from the UPS system.

Fig. 11. Battery report from the UPS.

Fig. 12. Bypass report from the UPS.

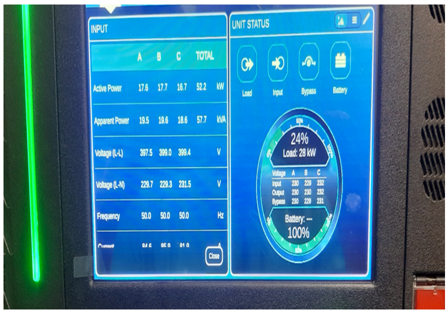

Fig. 13. Input report from the UPS.

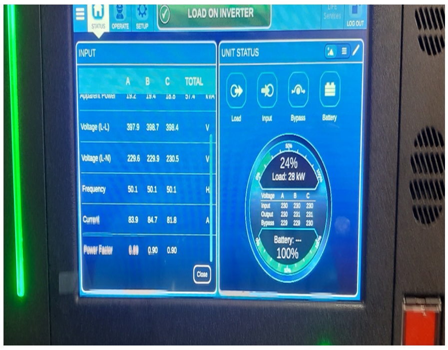

Fig. 14. Input report from the UPS (2).

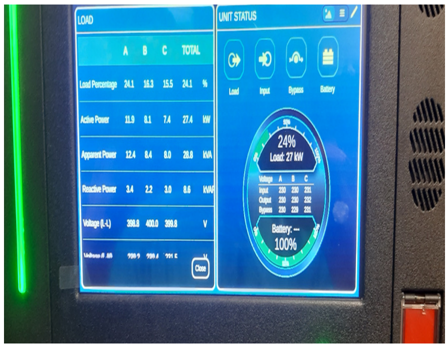

Fig. 15. Output report from the UPS.

All the mentioned parameter values were validated by physical measurements with calibrated current-meter, voltmeter, and frequency meter on the terminal points of the UPS. The GBMS proved to be reliable as it was accurately monitoring all vision battery modules and temperature within the BMS cabinet. Validation was done by connecting the BMS monitoring system software using RJ45 cables to the LAN point of the CBMS and the values were compared with what was shown on the GBMS screen.

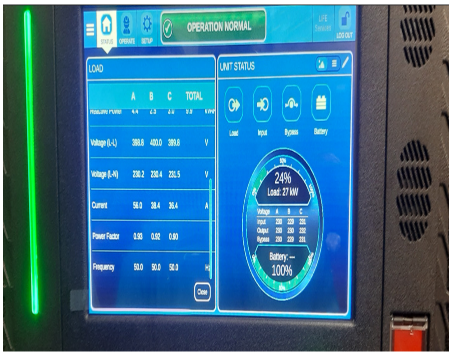

Fig. 16. Output report from the UPS (2).

III. CONCLUSIONS

The objectives from this research was to propose a Lithium-Ion battery product which was compatible to a Vertiv UPS/Inverter type, then integrate the two and evaluate the performance during charge and discharge, and also to assess the reliability and durability of the system. With the wind turbine currently incorporated with a Vertiv Inverter and a VRLA battery type system, there were certain drawbacks experienced and observed during operation similar to those mentioned in Table I.

The performance from the data observed in this research clearly showed why Lithium-Ion batteries are the optimum storing energy source for wind turbine applications. Over a 10-year period, the Lithium-Ion batteries provide significant TCO savings without the inconvenience and replacement cost of the lead-acid batteries. The longer lifespan and reduced maintenance needs of Lithium-Ion batteries produce a significant return on investment in less than five years. Lithium-Ion battery smaller size and reduced weight provide better flexibility for use in remote facilities and their superior performance can also help to ensure uptime and continuous operations for wind turbine projects. The combined advantages in cost-effectiveness, performance, and safety worth the initial investment, as Lithium-Ion batteries provide dependable long-term service.

The TP-100 Vision Lithium-Ion battery will be integrated to a 500W (7–rotor-blade) prototype with NACA-4412 blade design wind turbine in an original system in Soweto, Johannesburg. Based on the results observed during this research, the TP-100 Vision Lithium-Ion battery system proved to be feasible for a wind turbine system implementation in Soweto.

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