Lithium-Ion battery reliability prediction and management for deep diving autonomous underwater vehicles

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Lithium-Ion battery systems constructed from autonomous battery modules can provide unsurpassed capability for power supply required in autonomous underwater vehicle (AUV) applications. They have significant benefits when compared to alternative solutions. A lithium-Ion battery pack provides the highest specific energy and energy density, and long rechargeable battery life required for multi-missions deployment and persistent platform presence.

The safety and reliability of Lithium Ion batteries can be compromised in many ways, with cell failure or deliberate tampering being the most predominant types of failure. Lithium-Ion failure can have catastrophic consequences to human safety and platform integrity. The recent incidents with the Boeing 787 Dreamliner received great media coverage. However, incidents in the AUV domain are not unusual; the most recent incident was a fire of the Autosub 6000, which resulted in critical vehicle damage. It is therefore imperative to quantify the reliability of Lithium-Ion batteries in autonomous underwater vehicles so that risk mitigation actions can be devised and maintenance strategies implemented.

This paper quantifies the reliability of deep AUVs Lithium-Ion batteries based on two different approaches. First we use the standardized approach to quantify the battery reliability based on its design and operation lifecycle. Then we use statistical models to quantify the reliability of the battery cells based on empirical data of Autosub 6000 operational history, during which the AUV travelled a total of 3650Km and reached a maximum depth of 5600m.

Based on the Lithium-Ion battery reliability estimates we devise the level of redundancy required to achieve 95% confidence that the battery system will meet mission objectives. A maintenance programme is devised based on the estimated hazard rate.

**Keywords**: Lithium-Ion batteries, autonomous underwater vehicles, reliability, maintainability