Lithium-ion Battery System for U212NFS

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Abstract — The continuous technological improvement effort that always inspires its work led the Italian Directorate of Naval Armaments to push the National Industry to develop a new generation of Lithium-ion Battery System for the propulsion of the new Italian U212 NFS Submarine Class. Compared to a same volume Lead-Acid Battery, a Lion Battery ensures increased submerged endurance, both at low and at high speed, and a lower indiscretion rate. Furthermore, its maintenance is less frequent and less invasive and its life cycle is years longer. In order to combine improved performances and the highest functional safety on board a sophisticated vehicle, as just modern submarines can be, a specifically designed cell has been developing, sized to run within low charge/discharge rates, typical of an energy rather than a power storage. Cells R&D has been coming together with design and tuning of their Battery Management System by the same manufacturer in Italy.

1 Objective

Current strategic scenarios impose a continuous technological improvement also for an already unmatched design among underwater shipbuilding as the AIP U212-A born from the cooperation between Italy and Germany.

In a challenge as difficult as improving an already excellent project, Lion Batteries represent one of the best technological solutions to enhance the modern not nuclear submarines capability to store energy on board increasing their sthealtiness. Moreover, they guarantee the highest growth potential for the future and the greatest versatility both in military and civil environment-friendly applications coming from automotive and boat industry to stationary energy storage.

2 Introduction

Italian MoD considers scientific research and technological innovation strategic for social and economic growth of the whole Country. Pushing ahead research before to need new systems to develop with ever more enhanced and demanding requirements is fundamental in order to preserve knowhow and guarantee a leading role on the international cooperation scenario.

The ambitious effort to further increase the submerged endurance of the already unmatched U212A design leds to investigate various solutions, finally taking advantage of national results in the lion technology R&D and choosing an italian new generation propulsion battery as best engineering option to reach the target.

The battery is going to be implemented in the next Italian U212 Near Future Submarines by FINCANTIERI, exploiting the expertise coming from quite twenty years of cooperation with tkMS in designing, manufacturing and supporting the U212-A Submarine Class, and FAAM, a high world presence Italian firm in the Lion Batteries and Battery Management Systems (BMS) field.

3 Approach

Following a “continuous improvement” objective, the U212 NFS design collects some solutions already adopted onboard the German Navy 2nd batch, i.e. the propeller optimized cap combined with pre-swirled rudders, and some new Italian branded cutting-edge components, i.e. the new generation fluoro-pholimeric hull coating successfully tested on ITS Scirè, modular electrical masts and a new ballast tanks emergency blowing devices.

A lithium battery can already ensure an energy density in volume almost double that of a lead acid one. Furthermore, continuous technological improvement are in progress with a preview of capacity growth by an order of magnitude in a next future. Overall that means a lower indiscretion rate and a much higher submerged endurance at high speeds, ensuring evasion capacity when necessary, so survivability.

The work of the Industry, under the supervision of the submariner officers engineer of the Italian Directorate of Naval Armaments, focused on these main advantages, together with the potential of a faster charge and an increased battery life and maintainability, but mandatory guaranteeing maximum operating safety on board a sophisticated and complex mean, as just modern submarines can be.

In this aim, FAAM, developed a cutting-edge 65 Ah stylus cell, with electrodes properly conceived and designed, based on lithium-iron-phosphate chemistry, the most stable at high temperatures and strong mechanical stress, i.e. in situations of potential risk of fire or explosion due to a so-called thermal runaway. Particular attention is paid on cycle life length preventing chemical and mechanical ageing phenomena considering peculiar environmental conditions of a submarine.

Although the NFS hull will be stretched 1.2 m to house the new features of the combat system, the Lion design is U212A battery room volume driven, to achieve a valid

product for the upcoming retrofits, with the target of a conspicuous increase in endurance than U212 A.

4 Results

Cells, although in a prototypical version, have been tested, starting by preliminary electrical characterization and continuing with destructive tests.

Electrical characterization has been performed considering single cell charge and discharge rate onboard the submarine, resulting in current values – partial charges at 0.3C and discharges from 0.1C to 1C – meaning an energy, safer, application rather than a power application.

Destructive tests (external short circuit, shock, perforation) have been performed on cells fully charged according to the standard IEC62619 about safety requirements for large secondary cells and batteries based on alkaline or other non-acid electrolytes, in order to improve prototypes eliminating the risk of sparks, fire and gas release.

Moreover, cells will be contained into robust stainless steel shock proven cases, ensuring mechanical protection as well as a uniform temperature gradient across the whole battery and compensating the lightness of the lithium cells compared to lead accumulators.

Each case, or string, integrates a suitable number of cells connected in series to reach board network voltage, their cooling circuit and a first layer of passive and active safety devices as part of a first BMS level.

Each string has same dimensions of two lead acid modules and could be conceptually associated to a partial battery, capable of providing the nominal battery voltage through a DC/DC control converter.

Moreover, it is conceived to can be easily improved in capacity, just changing the cells with new ones once continuous technological improvement in lithium ions technology field will make their available.

The Battery Management System, properly designed and tuned by the same manufacturer of the cell, on the base of a principle considered absolutely winning in a so articulate sector, continuously checks temperatures, currents, voltages and electrical insulation, suitably intervening when unacceptable deviations occur, protecting both the battery and the submarine itself against damage propagation between adjacent cells.

Current international technical regulations, IEC 61508 first, impose a Safety Integration Level (SIL) based approach focused on compliance with U212 technical requirements (shock, EMC, environmental conditions) through an accurate hazard identification and risk assessment and reduction, always naturally inherent in the DNA of submariners, and here systematically applied under TÜV Rheinland's institutional seal.

However, just following an optimum high SIL means technical complication in design, prototyping and maintenance, with high feasibility risks. Fixed lower limit of the tolerable residual risk for the submarine and the crew greater than that so far offered by a lead acid submarine propulsion battery, as much passive safety measures as possible will be adopted at any level, from single cell to the whole battery system, to prevent any possible damage escalation with as lower SIL as possible.

In the meantime, main challenge is an enough accurate factory sorting of the cells to take advantage of their quite identical and uniform electrical behavior, needing a Battery Management System as more simple and less invasive as possible.

5 Future Work

This first phase of R&D will be conducted by 2020 to have all battery system components certified with regard to safety and militarization and well defined concerning electrical and geometrical dimensions and weights to be taking in account for the integration inside the submarine project by FINCANTIERI and tkMS. Since true trials are always the best, a second phase will follow in 2021 with the construction of the first complete battery system prototype to be installed inside a laboratory battery room mock-up in good time to be fully proven for the commissioning of the first of Class U212 NFS.

6 Conclusions

The U212-A program, as a magnificent example of *European Program*, involved and empowered two big prime contractors as Fincantieri and tkMS and their respective industrial and research partners coming from the excellences of involved Countries.

Nowadays, always looking for continuous improvement, the new U212 NFS project was born in Italy, but always with eyes adressed to European and international cooperation considering its benefits for submarine community.

As core of this project, the Italian Lion propulsion battery is already running its first steps, probably the slowest, but the most important for a safety driven and feasibility oriented design, with a complementary potential in the marine industry in general as environment friendly solution in many energy storage application.