UPDATE ON EXPANDING AVAILABILITY HORIZONS: NEW BATTERY TECHNOLOGIES IN INDUSTRIAL UPS SYSTEMS

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Abstract - Stored energy has multiple applications in an oil and gas processing facilities and this paper focuses on re-evaluating the traditional industrial AC and DC UPS systems (consisting of power electronics and battery) with the use of new battery technologies that can change the traditional architecture of the industrial sites. Considerations presented review basic industry demands for battery and UPS performance and the effect of removing limitations of current battery technologies, including gas emissions, temperature decay, aging, battery availability, storage, safety and recyclability.

The paper presents several important considerations that need to be made to select the correct battery technology based on the underlying application needs e.g. between energy density and power density. It also investigates the positive impact of new solutions on industrial site design requirements including battery rooms and outdoor installation. Thorough testing results are presented as well as field experience feedback. Illustrations for the paper are based on a prior installation reference, lab testing as well as performance of recent upstream and downstream facilities.

Index Terms — SMC: Sodium Metal Chloride, VRLA: Valve Lead Regulated Acid

I. INTRODUCTION

Industrial Uninterruptible Power Supply (UPS) systems rely on battery technologies to provide backup power in critical applications. Historically, Valve-Regulated Lead Acid (VRLA) and Nickel-Cadmium (NiCd) batteries have dominated industrial settings due to their availability and cost-effectiveness. However, these technologies come with challenges such as limited lifespan, high maintenance requirements, temperature sensitivity, and safety concerns.

In our previous paper [1], we conducted an in-depth evaluation of emerging battery technologies, particularly Lithium-Ion (Li-ion) and Sodium-Metal Chloride (SMC) batteries, in the context of industrial UPS applications. We compared these technologies based on key performance criteria, including operational continuity, maintenance intervention, lifecycle costs, safety, temperature resilience, and footprint efficiency. The findings demonstrated that both Li-ion and SMC batteries present significant advantages over traditional VRLA and NiCd technologies, offering improved reliability, reduced maintenance, and enhanced safety. Notably, SMC batteries emerged as a strong contender for industrial applications due to their unique characteristics, such as modular redundancy, resistance to thermal runaway, and ability to operate in extreme environmental conditions.

Beyond technical performance, the previous study highlighted the transformative impact of advanced battery technologies on industrial site design. The elimination of dedicated battery rooms, the potential for outdoor installations, and the reduction in cabling and infrastructure complexity were identified as key benefits. Additionally, advancements in Battery Management Systems (BMS) have enabled seamless integration with UPS electronics, improving monitoring capabilities and overall system availability.

Since the publication of our last paper, battery technology has continued to evolve, with new developments in electronics circuitry, performance optimization, and real-world application data. In this paper, we will review these advancements and examine practical case studies from industrial sites that have adopted these next-generation battery solutions, providing insights into their operational benefits and lessons learned from field deployments.

II. CURRENT SMC TECHNOLOGY OVERVIEW

A. Principles of Operation

Sodium-Metal Chloride (SMC) batteries operate as high-temperature secondary (rechargeable) batteries. Their electrochemical system consists of a molten sodium anode and a cathode composed of metal chlorides, primarily nickel (Ni) and iron (Fe), combined with sodium chloride (NaCl). The electrodes are separated by a solid-state ceramic electrolyte made of sodium-beta" alumina, which facilitates the transport of sodium ions while maintaining electrical insulation between the anode and cathode.

During charging, sodium ions migrate from the cathode through the electrolyte to the anode, where they are reduced to metallic sodium. During discharge, the sodium ions return to the cathode, where they react with chloride ions to form sodium chloride, releasing electrical energy in the process. The sealed design of the battery prevents gaseous emissions, eliminating the need for venting.

Key design characteristics of SMC batteries include:

1) **Hermetically Sealed Construction:** Prevents exposure to active chemical components and external contaminants.

2) **Solid Ceramic Electrolyte:** Provides high ionic conductivity while ensuring electrical separation between the electrodes.

3) **Controlled Operating Temperature:** Maintains an internal temperature of approximately 270°C to ensure consistent electrochemical performance.

4) **Modular Configuration:** Enables the connection of multiple cells in series or parallel to achieve the desired voltage and capacity.

5) **Integrated Battery Management System (BMS):** Monitors state of charge, temperature, and overall battery health, ensuring safe operation.

The operational characteristics of SMC batteries present several advantages. They exhibit high energy density relative to traditional battery technologies, allowing for a more compact system footprint. Their performance is stable over a wide range of ambient temperatures (-20°C to 60°C), reducing the need for environmental conditioning. SMC batteries also demonstrate long cycle life, with a capacity retention of over 4,000 cycles at 80% depth of discharge.

From a safety perspective, SMC batteries do not exhibit thermal runaway under normal operating conditions, differentiating them from certain Li-ion chemistries. The absence of gas emissions and venting requirements further enhances their suitability for enclosed or remote installations. Maintenance requirements are minimal due to the sealed design, which eliminates the need for electrolyte replenishment or frequent inspections.

When compared with other battery technologies, SMC batteries offer distinct performance trade-offs. Compared to VRLA and NiCd batteries, they have longer lifespans, lower maintenance requirements, and reduced environmental impact due to the absence of hazardous heavy metals. In contrast to Li-ion batteries, SMC batteries offer improved thermal stability and a lower likelihood of catastrophic failure while maintaining a competitive cycle life.

SMC batteries have been deployed in various industrial applications, including oil and gas facilities, offshore platforms, data centers, power plants, and remote installations. Their ability to integrate with UPS systems and reduce infrastructure complexity positions them as a potential alternative to conventional battery technologies. The subsequent sections will explore recent advancements in SMC technology and present real-world case studies demonstrating their application in industrial environments.

B. Summary of Battery Technology Comparison

Four battery technologies—VRLA, NiCd, Li-ion, and SMC—were previously assessed based on key parameters relevant to industrial UPS applications. The evaluation focused on factors such as energy and power density, cycle life, operational temperature range, maintenance requirements, safety considerations, and environmental impact.

VRLA batteries remain a widely used option due to their low initial cost; however, their relatively short cycle life and high maintenance needs pose challenges. NiCd batteries offer greater durability and operate effectively across a wider temperature range, but their environmental impact due to cadmium content is a significant drawback. Li-ion batteries provide high energy density and longer cycle life, yet their susceptibility to thermal runaway requires stringent safety measures. SMC batteries were found to offer a combination of long lifespan, thermal stability, and low maintenance, making them well-suited for critical industrial applications.

The following table presents a comparison of these battery technologies based on the evaluated criteria:

Parameter	VRLA	NiCd	Li-ion	SMC
Energy Density	Low	Medium	High	Medium
Power Density	Low	Medium	High	High
Cycle Life	500-1,500 cycles	2,000-4,000 cycles	3,000-5,000 cycles	4,000+ cycles
Temperature Range	-10°C to 40°C	-20°C to 50°C	-20°C to 60°C	-20°C to 60°C
Maintenance	High	Moderate	Low	Low
Safety	Moderate (risk of leaks)	Moderate (contains cadmium)	Lower (thermal runaway risk)	High (no thermal runaway)
Environmental Impact	High (acid disposal)	High (toxic metals)	Moderate (fire risk)	Low (no hazardous materials)

This evaluation highlights that while each technology has specific strengths and limitations, SMC batteries demonstrate a favorable balance of performance, reliability, and safety. Their ability to operate in extreme environments with minimal maintenance and without the risk of thermal runaway distinguishes them as a viable alternative for industrial UPS applications. The next section will review advancements in battery technologies since the original study and explore real-world applications of SMC batteries in industrial settings.

III. CONSIDERATIONS FOR THE UPS DESIGN

While the chemistry of Sodium-Metal Chloride (SMC) batteries has remained unchanged and proven reliable in the field, recent developments have focused on enhancing the integration of battery electronics with UPS systems. The objective is to create a **symbiotic, intelligent system** that optimizes power availability and enhances system reliability through improved communication and control strategies.

A. Redundancy Configuration

The redundancy configuration of SMC battery systems enables n+1 or n+m redundancy, controlled through direct communication between the battery charger or AC UPS and each battery module. In the event of an unlikely failure in one module, the UPS detects the issue and sends a signal to activate a redundant battery module, ensuring continuous power availability. Unlike conventional lead-acid systems, where battery redundancy is typically achieved through large 2×100% or 2×50% configurations, the modular and parallel arrangement of SMC batteries reduces the overall footprint while maintaining high availability. Additionally, SMC cells fail in a short-circuit mode, unlike lead-acid cells, which fail in an open-circuit mode, further improving system reliability.

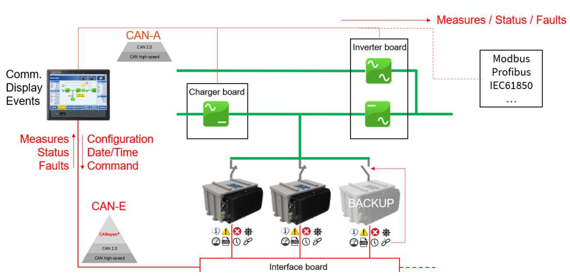
B. Replacement Management

Replacement management benefits from the stable chemistry of SMC batteries. New and old modules can be combined in the same system without performance degradation, and each module (~10 kWh) is hot-swappable, ensuring replacements can be performed without interrupting operations. Because SMC modules can be stored in a completely inert state without self-discharge, they retain full capacity after long-term storage. Tests on a module stored for 15 years showed 99.6% of its original capacity after a few charge-discharge cycles.

C. Interface and Communication

The interface and communication between the UPS and battery modules is managed via a CAN open protocol. Each module's BMS oversees:

- Thermal management, ensuring optimal service temperature
- Charge regulation for efficient energy storage
- Real-time monitoring and diagnostics, disconnecting faulty modules when necessary
- Remote maintenance, allowing data collection and supervision from a central location



D. Battery Diagnostics

UPS connectivity solutions now integrate battery diagnostics, providing a single point of connection and monitoring for the entire system. The UPS continuously assesses module performance, battery state of charge (SoC), and depth of discharge (DoD), enabling automated load-shedding decisions based on real-time capacity rather than estimated time-based calculations. This allows industrial operators to maximize energy utilization and extend backup duration before critical loads are shed.

D. State of Charge and Depth of Discharge Management

Advancements in SoC and DoD management further refine battery utilization strategies. Unlike conventional monitoring systems, which rely on approximations, SMC battery BMSs provide highly accurate real-time data, optimizing discharge cycles and ensuring reliable backup power availability under all operating conditions.

These developments in UPS and battery system integration contribute to increased reliability, reduced maintenance, and optimized power availability in industrial applications. The next section will present real-world case studies demonstrating these enhancements in operational environments.

IV. CONSIDERATIONS FOR INDUSTRIAL SITE DESIGN

These advancements in UPS and battery integration have a direct impact on industrial site design, influencing critical aspects such as the elimination of dedicated battery rooms, a reduced system footprint, lower HVAC requirements, improved offshore certification compliance, and the feasibility of outdoor installations. Furthermore, these design optimizations contribute to lower total cost of ownership (TCO), enhanced recyclability, and a reduced carbon footprint, aligning with sustainability objectives for industrial power solutions.

- Battery room
- Footprint
- HVAC
- Offshore certification
- Outdoor installations
- TCO
- Recyclability
- Carbon footprint reduction

V. CONSIDERATIONS FOR MAINTENANCE PERSONNEL

A. Storage & installation

SMC batteries minimize the risk of thermal runaway and explosions, enhancing overall safety in handling and operation. Furthermore, they perform well across a wide range of temperatures, making them suitable for various storage environments, including those with extreme temperatures.

The Initial discharge test for VRLA batteries is normally performed during the commissioning phase at the installation site as part of the SAT. With SMCs, this test can be done easily upfront at the factory during the FAT. It reduces the workload during the SAT what is always an advantage especially for units installed in remote locations.

B. PPE, risks management

The battery module is equipped with a safety switch. which isolates the +DC line from the power cell as shown on figure 1. When the terminal connector cover is removed, it activates a contact which automatically opens the line contactor. Hence when active parts become physically accessible to the maintenance technician, there is no voltage on the terminals anymore. This feature is a significant improvement compared to historical batteries technologies because people are no longer exposed to a risk of electrical shock or arc flash. Maintenance procedures are simplified accordingly.

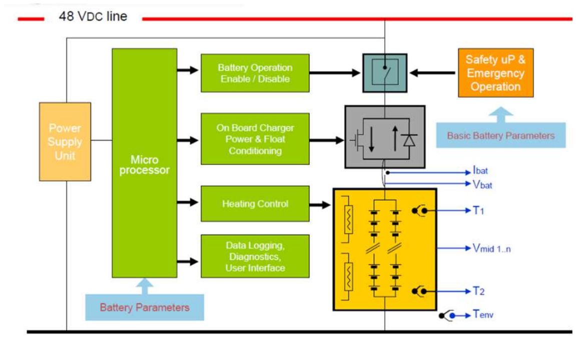


Figure 1

Manipulation of VRLA batteries require specific PPEs to protect maintenance technicians against acid splashes. In addition, some regulations ask for installing and maintaining eyes washing facilities (Article 320 of NFPA70E [2]). SMC batteries don't require such measures what makes a clear simplification in terms of work practices and people risk exposure.

C. Destruction

Sodium batteries do not rely on toxic materials like cadmium or lead, which are commonly used in historical technologies. This reduces the environmental impact for end-of-life management and reduces recycling costs.

VI. PROJECT ILLUSTRATIONS

The first SMC module was introduced in 2020 in Oil & Gas facilities. Since then, the installed based scaled up and as 2025, 1000+ SMC modules are currently in service. It gives now 5 years of operational experience feedback. Long term reliability performance requires extra years of operation and extra data points to be assessed. However, the size of the fleet in service now and the timeframe are significant enough to collect data and to confirm the promising performance demonstrated by the pilot projects. The 3 applications below illustrate the added value brought by the introduction of SMC battery technology at an industrial scale.

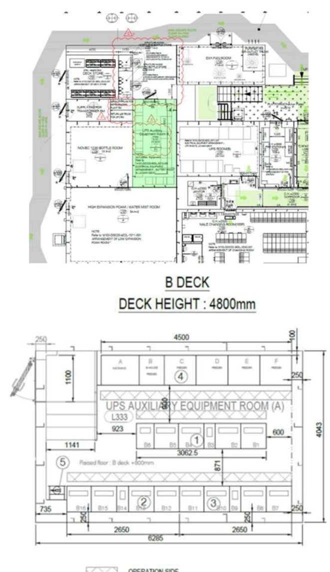
Application N°1	Application N°2	Application N°3
Upstream Offshore	Upstream Onshore	Downstream
FPSO	Gas field	Refinery
South America	Asia/Pacific	Europe/ North America
172 SMC modules installed	72 SMC modules installed	20 SMC modules installed

A. Application N°1

Weight and space savings are key targets when designing competitive FPSOs. The surface of battery rooms is directly proportional to the amount of energy to be stored. In that perspective, the usage of the SMC batteries brings a decisive advantage. Furthermore, because of H2 emissions when recharging, VLRAs systems require extra ventilation facilities. The size of HVAC system (and hence its footprint) decreases as well with sodium batteries because it accepts higher temperature environment. Theoretical features advocates for the extensive deployment of SMC batteries on FPSOs. On recent projects, both VRLA and SMC solutions were studied. The outcome demonstrated that the surface of the battery room is halved in average when using SMCs compared to VRLAs (Table 1). The TCO was systematically in favor of SMCs, hence sodium batteries were selected for those projects. One extra competitive advantage valuable for offshore assets is the limited preventive maintenance required by SMC batteries. The need for sending qualified technicians on the FPSO to perform measurement and cell preventive replacement is less frequent. The example is given for a one-hour autonomy application. The value of installing SMC batteries increases with the autonomy duration. The longer the autonomy, the greater the saving of space.

	FPSO A (footprint of battery bank)
VRLA	10.2m²
SMC	4.3m²

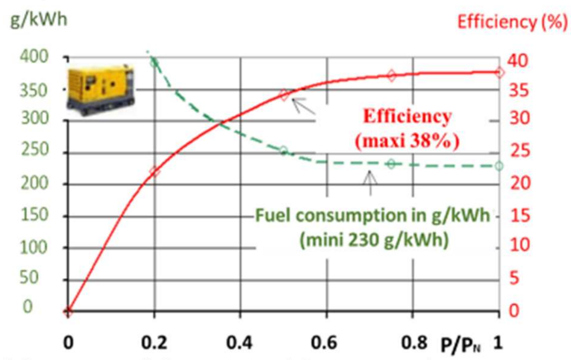
Table 1

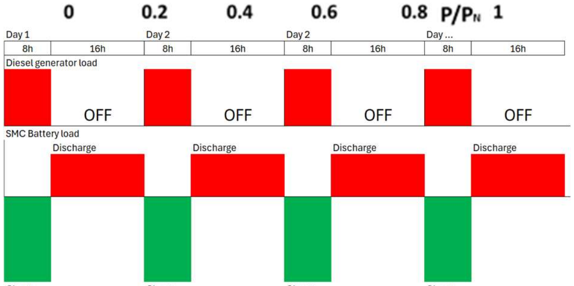


B. Application N°2

VRLA batteries require recurring preventive maintenance to ensure proper and safe operation. Therefore, systems need to be visited on a regular basis. On oil and gas facilities, equipment might be operated in remote areas and might be spread over many locations separated by several dozen kilometers of distance. In that perspective, it becomes a constraint to perform the preventive maintenance because it takes a lot of time to move to each location, especially when transportation infrastructure is limited to access to the location where the equipment stands. Specific authorizations and precautions might be required for qualified maintenance people as well. SMC batteries offer a significant competitive advantage in that situation because of their low preventive maintenance requirements. Such locations might be submitted to extreme climate condition. Batteries for the application taken as example in this paper are submitted to 35+ Celsius degrees permanently.

In addition to above constraints, on this application UPS are fed by diesel generators with no access to a utility network. The generators need to be refueled on a regular basis. When working at low load, the efficiency of the engines is poor what requires frequent rotation for refueling. Rather than operating the generators 100% of the time at low efficiency pint, the solution was to run them intermittently and set them at their optimum efficiency operating point when running. Batteries are used as energy buffers. This running mode allows to increase the interval between refueling. The generators charge the batteries 8h per day at high load, then they stop, and the batteries take over (ON/OFF mode). Hence in that application the battery charging/discharging cycle is very severe because it charges and discharges every day. VRLA batteries wouldn't accept such cycling and would fail within a short period of time (1 to 2 years) which is not acceptable. SMC batteries were used because they perfectly fit for the requirements of this application due to their high cycling capabilities and robustness to high operating temperatures.





The operating point of the generator is adjusted based on the SOC of the battery. The SOC is monitored by the UPS and one of the challenges was to calibrate the control threshold at which the batteries move from discharge to recharge mode. It was especially difficult to tune because this application has a dual UPS architecture. Changes in the firmware of the system give encouraging results to reach expected refueling saving targets.

C. Application N°3

When becoming obsolete, UPS and DC chargers equipped with VRLA batteries systems must be replaced with limited downtime for the process. To do so, the traditional way is to install the new system aside the existing one in hidden time, energize it and transfer the loads. The alternative is to remove the old system and install the new one instead. This second option is not preferred because it extends the duration of the shutdown to perform the installation and the load transfer.

It is not uncommon in mature refineries and petrochemical plants to see substations overflowing with electrical equipment. Over the years, expansion projects installed new panels and took all the remaining available space. Hence, installing a new UPS system aside the existing one is not always possible due to lack of space.

If there is enough space in the existing substation and if the ventilation system capability is sufficient, the decision to shift from VRLA to SMC batteries needs to be assessed depending on the actual lifetime of the existing VRLA battery system. Table 2 gives an overview of which retrofit solution is better according to the expected lifetime.

Lifetime of initial VRLA battery bank	Best retrofitting technology (Best TCO)
3y	SMC
5y	SMC
7-10y	SMC/VRLA
>10y	VRLA

Table 2

If the lifetime of VRLA batteries is greater than 10y, a replacement in kind is recommended because it remains the most competitive solution. In that case, there is no incentive to use SMCs because the CAPEX was spent at the time when the substation was built and there is no further credit to expect. With current batteries prices, based on OPEX comparison only, recent TCOs calculations on mature facilities demonstrated that VRLA remains the best solution.

When lifetime is low due to poor environmental conditions (storage and/or operation), retrofitting VRLA batteries to SMC becomes very interesting economically.

When there is not enough remaining space in the existing substation or if there is a bottleneck in the ventilation system, the usage of SMCs batteries is an excellent solution because its footprint is much smaller. It leads to very compact new systems which can fit in the substation, or which even can be put outside of the building. Furthermore, having 2 VRLA systems running at the same time requires increasing the ventilation capability temporarily until the old system is decommissioned. With the SMC batteries, there is no need to modify the ventilation system.

II. CONCLUSIONS

The re-evaluation of traditional industrial AC and DC UPS systems with new battery technologies offers significant potential to transform oil and gas processing facilities. By addressing key industry demands such as performance, safety, and recyclability, these advancements can overcome the limitations of historical battery technologies. The careful selection of battery system, tailored to specific application needs, can enhance energy and power density, leading to more efficient and sustainable operations. The positive impacts on industrial site design, including optimized battery rooms and outdoor installations, are supported by thorough testing and field experience. This paper underscores the importance of adopting innovative battery solutions to meet the evolving needs of the industry and improve overall operational efficiency. The current fast growing installed base is showing very promising results

* Despite the higher front cost of the SMC technology, both CAPEX and OPEX can be drastically reduced. Total cost of ownership (TCO) is often in favor of this SMC battery technology.
* The UPS system availability is drastically improved thanks to the intrinsic technology reliability and thanks to the modular redundant solution.
* A new development for direct outdoor application, where high temperature and other constraints are present, thus jeopardizing the conventional battery technologies, is currently under feasibility study

III. ACKNOWLEDGEMENTS

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VI. REFERENCES

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[2] NFPA 70E, 2024 Standard for Electrical Safety in the Workplace

IV. VITA

Joe Marquardt graduated from Clemson University with a BSEE in 1995 and has worked for ExxonMobil performing roles in electrical, instrument, and process engineering with additional roles in project management. He is presently in the global rols of Senior Principal Engineer for the Electrical discipline

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