

Safety of Solar and Electric Boats

Sandith Thandasherry, CEO (NavAlt Solar and Electric Boats)

sandith@navgathi.com

ADITYA, India's first solar ferry^[1], by its successful operation and great savings has demonstrated a whole new way for transportation on water - a solution that is better and cheaper^[2]. Many new government transport departments, boat operators, other organisations are looking at replicating this success. In this context, we feel it is important to put down the essential standards that enabled the success of ADITYA. Taking shortcut and diluting safety standards are extremely dangerous and must be avoided. A spectacular failure will hamper the progress of adoption of solar-electric boats across the country.

This document takes you through the key standards that was followed in ADITYA and is recommended for any new solar-electric boats. We have included information about the importance of following leading classification society standards and international safety standards for boat construction, propulsion power train (motors, battery systems, monitoring) and other safety systems. It is to be noted that in case of automobiles there is sufficient time to escape in case of runaway. This can be used as guide by anyone who takes safety seriously and understand the importance of safety standards in boating industry.

Overall Safety of Construction

- Build under IACS member Classification Society^[1].
- Preferably leading IACS member like ABS¹, BV², DNV-GL³, LR⁴, NK⁵ or IR⁶

Stability

- Build as catamaran for higher margin of stability^[1].
- Designed for overcrowding by 100% meeting static stability conditions (Initial GM and others).

Battery System

- The battery modules including the BMS system must be suitable for the **installation on marine vessels** within metal enclosures located inside hull.

¹ American Bureau of Shipping - <https://ww2.eagle.org/en.html>

² Bureau Veritas - <https://group.bureauveritas.com>

³ Det Norske Veritas - Germanischer Lloyd - <https://www.dnvgl.com>

⁴ Lloyds Register - <https://www.lr.org/en/>

⁵ Nippon Kaiji Kyokai - <http://www.classnk.com/register/regships/regships.aspx>

⁶ Indian Register of Shipping - <http://www.irclass.org>

- Battery must be approved by the above leading IACS class society for application for main propulsion. **A good reference is the DNV-GL for Lithium Batteries ([DNVGL-CP-0418](#))**. See details **Reference 1**.
- Battery must be approved by the above leading IACS class society for installation in machinery space (Category A, see Reference 4). **This rule requirements refer to DNV-GL for Environment test ([DNVGL-CG-0339](#)) and list of IEC Codes**. See details **Reference 2**.
- **Battery must conform to IEC 62133:2012 standards for testing**. See details **Reference 3**.
- Battery must have **IP56 ingress protection**. According to the CPRI norms it must follow IEC:60529, IS:12063, IS:60947 (P-1) 2004 for IP ratings and environmental tests mentioned.
- **Battery ventilation** must be designed to ensure lifecycle operating in temperature higher than 30 degrees my monitoring charge and air cooling by PLC (programmable logic controller)
- Manufacturer must take back the battery for recycling as per international guidelines (EU).

Motor

- Motor must be approved by the above leading IACS class society for application in marine propulsion.

Solar Panels

- High quality solar panels with low degradation of performance.
- Meet IEC 61701: Salt Mist Corrosion testing.

Charge Controller

- MPPT type with 5 years warranty.

Remote Monitoring

- Battery cell parameters to be remotely monitored on a cell level monitoring
- Energy production/consumption/storage to be remotely monitored

System Safety

- Three level of warning required for critical components in terms of temperature, state of charge, voltage, current, sensor failure to protect the system.
- First level is usually information as precursor to second level. The next level forces a slowdown and the third level forces shutdown of necessary equipment to protect it.

References

[1] - Sandith Thandasherry, *High fives for solar-powered ferry ops*, *Ship & Boat International*, Jan/Feb 2018

[2] - Sandith Thandasherry, *Economics of ADITYA*, *IEEE 2018*, Under review

Reference 1 - DNVGL-CP-0418

- Type test for battery cell
 - External short circuit test - IEC 62619 8.2.1 (alternatively IEC 62281 T-5 or UN38.3 T-5)
 - Impact test-IEC 62619 8.2.2 (alternatively IEC 62281 T-6 or UN38.3 T-6)
 - Thermal abuse test-IEC 62619 8.2.4 (alternatively IEC 62281 T-2 or UN38.3 T-2)
 - Overcharge test-IEC 62619 8.2.5 (alternatively IEC 62281 T-7 or UN38.3 T-7)
 - Forced discharge test-IEC 62619 8.2.6 (alternatively IEC 62281 T-8 or UN38.3 T-8)
- Tests for Lithium battery system
 - Propagation/Internal thermal event test -IEC 62619 8.3.3
 - Overcharge with voltage test- IEC 62619 9.2.2; alternatively IEC 62133-2
 - Overcharge with current test- IEC 62619 9.2.3; alternatively IEC 62133-2
 - Overheating control test- IEC 62619 9.2.4; alternatively IEC 62133-2
 - Sensor failures test- Detection of all failure modes of the sensors
 - Cell balancing test- According to specification
 - SOC validation test- According to specification
 - Safety function test
 - emergency stop function
 - alarms and shutdowns
 - high voltage interlock loop (HVIL)
 - temperature protection BMS
 - overvoltage protection BMS
 - undervoltage protection BMS
 - communication Failure
 - additional tests based on the implemented safety functions, ref FMEA for the BMS.
 - Capacity validation test- According to specification, IEC 62620 may be used
 - Di-electrical strength (high voltage test)-DNV GL
 - Insulation resistance test-DNV GL rules for classification – Ships
 - Pressure test of cooling system test-In case of liquid cooled system

Reference 2 - DNVGL-CG-0339

- Environmental tests for batteries (Refer Category A details below)
 - Vibration test
 - Dry heat test
 - Damp heat test
 - Cold test
 - Corrosion test
 - Flame retardant test
 - EMC test

Reference 3 - IEC 62133:2012

- The standard requires that insulation resistance between the positive terminal of the battery and any externally exposed metal surfaces (excluding electrical contacts) is not less than 5MΩ at 500VDC.
- Internal wiring and its insulation shall be rated to withstand the maximum voltage, current and temperature requirements of the battery. Adequate clearances and creepage distances shall be maintained and the mechanical integrity of internal electrical connections shall be sufficient to accommodate the conditions of the foreseeable misuse tests.
- The standard requires that cells and battery cases incorporate a pressure relief mechanism or be constructed so that they will relieve excessive internal pressure so as to prevent rupture, explosion and self-ignition.
- The standard requires that tests are performed on specific numbers of cells or batteries. Cells or batteries must not be more than 6 months old. All tests are conducted at +20°C unless otherwise specified.
- The standard states that repeated exposure to high and low temperatures shall not cause fire or explosion. This is tested by subjecting fully charged cells or batteries to an ambient temperature of +75°C for 5 hours. There shall be no fire, explosion or leakage.
- The standard states that vibration encountered during transportation shall not cause leakage, fire or explosion. This is tested by subjecting fully charged cells or batteries to a simple harmonic motion. The cell or battery is visually inspected 1 hour after the test. There shall be no fire, explosion or leakage.

Reference 4 - Category A

- The system can safely install at all other locations of Machinery spaces, Control room, Accommodation and ship bridges at temperature range of 0 to 45°C. Temperature test will be at 55°C.
- The system can safely install at any locations (where special precautions are taken to avoid condensation) of Machinery spaces, Control room, Accommodation, ship bridges, pump rooms and open deck at relative humidity up to 96% at all relevant temperatures.
- The system can safely install in other locations of Machinery spaces, Control room, Accommodation, ship bridges, pump rooms and open deck at frequency range 2-13Hz and amplitude 1.0mm peak value. Frequency range 13.2-100Hz, Acceleration amplitude 0.7g.
- The system can safely install at all locations Machinery spaces, Control room, Accommodation, pump rooms. The system is tested with Electromagnetic compatibility test for testing its immunity and emissions radiated and conducted.
- Enclosure must be suitable for safe installation on control room, Accommodation and bridges with ingress protection IP20.