Requirements for

Hybrid and All-Electric Power Systems for Marine and Offshore Applications

ABS

April 2024

REQUIREMENTS FOR

HYBRID AND ALL-ELECTRIC POWER SYSTEMS FOR MARINE AND OFFSHORE APPLICATIONS
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American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Foreword *(1 April 2024)*

ABS has developed a series of Requirements for hybrid electric technologies (*Lithium-ion Batteries Requirements*, *Supercapacitor Requirements*, *Fuel Cell Power Systems Requirements*, *DC Power Distribution Requirements*). With hybrid power systems in wide use in the marine and offshore industries, ABS provides owners and operators notations for different arrangements and configurations where electric power generation and energy storage technologies are used. This document focuses on the integration of those new technologies with conventional power generation to develop a hybrid electric power system. The document also addresses vessels incorporating an all-electric power system.

A hybrid electric power system utilizes multiple sources of power, both non-conventional sources (e.g., batteries, super-capacitors, fuel cells) and conventional sources (e.g., internal combustion engine driven generator sets, shaft generator driven by main engine).

An all-electric power system utilizes only non-conventional sources of power. Vessels with such arrangements also incorporate specialized power and energy management systems. The application of hybrid electric power systems and all-electric power systems on board the vessel may reduce NO_x, SO_x and CO_2 emissions.

Current trends in the yacht industry have also resulted in increased demand for hybrid electric installations. This document introduces requirements for the design, installation, and testing of hybrid electric power systems and all-electric power systems on yachts too.

The current edition of the ABS *Rules for Building and Classing Marine Vessels* and/or ABS *Rules for Building and Classing Mobile Offshore Units* are to be used in conjunction with this document.

The February 2022 edition of this document includes requirements and guidelines for wind and solar photovoltaic (PV) electric power generation systems when installed on vessels and integrated into hybrid electric power systems. These requirements have been incorporated into Sections 5 and 6 to be applied in conjunction with the existing requirements for the optional **HYBRID IEPS** notation as appropriate. Addition of new definitions, references and required submittal information supports Section 5 and Section 6 related to wind and solar PV electric power generating systems.

The July 2022 version changes the document type from “Guide” to “Requirements”. “Requirements” documents contain mandatory criteria for Classification and issuance of Class Certificates, while Guides contain only requirements for optional Notations (see 1-1-4/1.5 of the ABS *Rules for Conditions of Classification (Part 1A)*). The title is changed from "*Guide for Hybrid Electric Power Systems for Marine and Offshore Applications*" to "*Requirements for Hybrid Electric Power Systems for Marine and Offshore Applications*". Accordingly, editorial changes are made throughout this document.

The April 2024 version updates the document title from “*Requirements for Hybrid Electric Power Systems for Marine and Offshore Applications*” to “*Requirements for Hybrid and All-Electric Power Systems for Marine and Offshore Applications*.” “**IEPS**” is removed from the “**HYBRID IEPS**” notation for simplicity. Two new operating modes, “[**OCC**]” and “[**EM**]” are added to the “**HYBRID**” notation. This update also introduces new notations, “**All-Electric Vessel**”, “**HYBRID Ready**”, and “**All-Electric Ready**” and requirements for these notations covering system and equipment design, installation, safety, and automation. It also details electrical requirements for connecting a vessel to an offshore charging connection, including position keeping requirements for the vessel to be charged.

This document becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically to rsd@eagle.org.

REQUIREMENTS FOR

HYBRID AND ALL-ELECTRIC POWER SYSTEMS FOR MARINE AND OFFSHORE APPLICATIONS

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SECTION 1
General

1 Introduction *(1 April 2024)*

Currently, the primary form of commercial ship propulsion is internal combustion engines delivering thrust directly to the water via a shaft and propeller.

However, with ongoing technological advances, an increasing number of options are now available to meet the specific needs of a vessel with a range of operational modes while meeting current and foreseen environmental regulations. One alternative to the conventional mechanical propulsion arrangement is an electric propulsion system, which allows for the propulsion requirements of the vessel to be provided by electric propulsion system, with electric propulsion motors and an electric Energy Storage System (ESS).

Hybrid and all-electric power systems offer the opportunity to improve safety, reliability, operational efficiency, fuel consumption, and environmental footprint. They may extend the equipment maintenance intervals when compared to conventional power systems.

This document provides requirements for the design, construction, testing and survey of vessels utilizing hybrid/all-electric power systems.

3 Application and Scope

3.1 Application *(1 April 2024)*

This document is applicable to marine and offshore assets designed, constructed, or retrofitted with a hybrid and/or all-electric power system. When hybrid or all-electric power systems are installed, compliance with the requirements of this document is mandatory.

This document is intended for use in conjunction with recognized international/national codes and standards, as well as the latest edition of the applicable ABS Rules, and/or Guides and Requirements documents, as listed in 1/11.1,1/11.3, and 1/11.5.

3.3 Scope *(1 April 2024)*

The requirements of this document are intended for installations of a variety of hybrid electric power systems such as combination of conventional power generation (generator, shaft-generator), energy storage systems (battery, supercapacitor), fuel cell power systems, and renewable energy sources {e.g., solar and wind (electric) power} on marine and offshore installations.

The requirements of this document are also intended for installations of all-electric power systems without the use of internal combustion engines as main source of power.

For all-electric vessels, the use of internal combustion engines operating on conventional fuels is permitted as prime movers for the emergency generator.

The unique requirements for the design, installation, and testing of hybrid electric power system and/or all-electric power system on yachts are also addressed.

The scope of this document also encompasses hybrid electric power systems and all-electric power systems with integrated lithium-ion battery systems, supercapacitor systems, and fuel cell power systems as detailed in the applicable ABS Guides and Requirements documents as referenced in 1/11.1.

5 Classification Symbols and Notations

5.1 Notations

5.1.1 Hybrid Notations for Marine Vessels and Offshore Units *(1 April 2024)*

Upon request, the following optional notations are offered for vessels installed with a hybrid electric power system.

i) **HYBRID**[1]

Where a vessel is arranged to use one or more sources of power (e.g., energy storage system (ESS) such as battery, supercapacitor, fuel cell system**,** wind, solar PV and conventional power generation (including generator(s) and/or shaft generator(s)), a system designed, constructed and tested in accordance with this document may be assigned the Class Notation **HYBRID.**

ii) **Descriptive Letters for Operating Modes**

Vessels complying with 1/5.1.1 i) above and are also fitted with means to operate under one or more specific operating modes as identified in 3/Table 2 may be assigned the Class Notation **HYBRID** and **[descriptive letters, describing operating modes]**, (e.g., **HYBRID [LEE], HYBRID [PMT]**, etc.).

Descriptive letters for the specific operating modes can be found in 3/5.3.2 and 3/Table 2.

iii) **HYBRID Ready (Level: 1C, 2D)**

A vessel powered by conventional internal combustion engines may be converted in the future to a hybrid electrical power system vessel by the addition of non-conventional power sources such as fuel cells, electrical storage systems (ESS) consisting of batteries, supercapacitors, or other technologies to form the power generation and propulsion system of the vessel.

A vessel incorporating such future conversions in accordance with this document may be assigned the Class Notation **HYBRID Ready**. The assignment of the **HYBRID Ready** Notation provides two options, which are are specified in 1/5.1.3

5.1.2 All-Electric Notations for Marine and Offshore Vessels *(1 April 2024)*

Upon request, the following optional notations are offered for vessels installed with an all-electric power system.

i) **All-Electric Vessel**

Where a vessel is fitted with means to operate on all-electric power systems.

ii) **Descriptive Letters for Operating Modes**

Where a vessel is arranged to comply with 1/5.1.2 i) above and is also fitted with means to operate under one or more specific operating modes as identified in 3/Table 3, the vessel may be assigned the Class Notation **All-Electric Vessel** and **[descriptive**

letters, describing operating modes], (e.g., **All-Electric Vessel [SCN], All-Electric Vessel [OCC]**, etc.) found in 3/5.3.3 and 3/Table 3.

iii) **All-Electric Ready (Level: 1C, 2D)**

A vessel powered by conventional internal combustion engines or hybrid electric power systems may be converted in future to an all-electric power system vessel by the addition of non-conventional power sources such as fuel cells, electrical storage systems (ESS) consisting of batteries, supercapacitors, or other technologies to form the power generation and propulsion system of the vessel.

A vessel incorporating such future conversions in accordance with this document may be assigned the Class Notation **All-Electric Ready**. The assignment of **All-Electric Ready** Notation provides two options, which are specified in 1/5.1.3.

5.1.3 Ready (Level: 1C, 2D) *(1 April 2024)*

i) **Ready 1C- Concept Design Review**

The Concept Design Review is a high-level evaluation of the suitability of a vessel design to incorporate a hybrid/all-electric power system. The high-level evaluation considers if the power system and general arrangements of the vessel can physically encompass the necessary equipment, in compliance with the requirements in this document at the time of the review. Upon satisfactory completion of this review level, ABS will assign a class notation, e.g., **HYBRID Ready 1C**/**All-Electric Ready 1C** to indicate the Concept Design Level. The concept design is to consider accommodating a specific type of system/systems, so that the same type of system can be installed in the future.

ii) **Ready 2D- Detail Design Review**

This Level is additional to Ready 1C, and it is categorized in separate design groups identifying the different components of the complete design.

The drawings and supporting documentation are to be reviewed for compliance with this Requirements document and the base Rules applied for Classification of the vessel. The detailed design is to evaluate specific systems, components, structural elements, or the complete system design.

Upon satisfactory completion of this review, ABS will assign a class notation, e.g. **HYBRID Ready 2D**/**All-Electric Ready 2D** to indicate the detail design stage review including descriptive letters for the component(s) or system(s) for which the design was reviewed. The detailed drawings could then be used as part of the retrofit project pending Class and flag state agreement at the time of installation.

Descriptive letters for the specific operating modes can be found in 3/Table 2 and 3/Table 3.

Note:

1 Internal combustion engine driven generator sets and shaft generators by themselves alone do not meet the criteria for HYBRID.

5.3 Notation Scheme Designation *(1 April 2024)*

The optional notations are organized as denoted in 1/5.3 Table 1 below:

For description of the operating modes, see 3/5.3.

TABLE 1
Designation Scheme of Notations *(1 April 2024)*

Notation	*Level*	*[Operating Mode]*
HYBRID		**HYBRID [LEE, PMT, PBU, PTO/PTI, SCN, OCC, EM]**
HYBRID Ready	**1C**	**HYBRID Ready [LEE, PMT, PBU, PTO/PTI, SCN, OCC, EM]**
	2D	
All-Electric Vessel		**All-Electric Vessel [PMT, PBU, SCN, OCC]**
All-Electric Ready	**1C**	**All-Electric Ready [PMT, PBU, SCN, OCC]**
	2D	

Note:
Operating Modes: Low-Exhaust Emission **[LEE]**, Power Management **[PMT]**, Power Backup **[PBU]**, Power Take-Off/ Power Take-In **[PTO/PTI]**, Shore Connection **[SCN]**, Offshore Charging Connection **[OCC]**, Electric Mode **[EM]**

7 Terminology *(1 April 2024)*

All-Electric Power System. A power system made up of one or a combination of energy storage system (ESS) and/or energy transformation device (ETD), including other non-conventional sources of power {e.g., solar and wind (electric) power}. An internal combustion engine may be used as an emergency source of power only.

All-Electric Vessel: A vessel fitted with means to operate on all-electric power systems.

Battery Management System. An electronic system possessing a battery module/pack that can cut power in case of overcharge, overcurrent, over-discharge, and overheating. It monitors and/or manages its state, calculates secondary data, reports that data, and/or controls its environment to influence the battery's safety, performance, and/or service life. [*IEC 62619*]

Battery Cell. The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, and terminals that is a source of electrical energy by insertion/extraction reactions of lithium ions or an oxidation/reduction reaction of lithium between the negative electrode and the positive electrode.

Battery Module. A group of battery cells connected together in a series and/or parallel configuration with or without protective devices and monitoring circuitry. [*IEC 62620*]

Battery Pack. An energy storage device comprised of one or more cells or modules that are electrically connected. It has monitoring circuitry that provides information to a battery system. [*IEC 62620*]

Battery System (Array). A system comprised of one or more cells, modules, or battery packs. It has a battery management system to cut power in case of overcharge, overcurrent, over-discharge, and overheating.

Battery Space (Compartment). The space in which the battery system is physically located.

Blocking Diode. A diode connected in series with module(s), panel(s), sub-array(s), and array(s) to block reverse current into such module(s), panel(s), sub-array(s), and array(s).

Brake. A device capable of reducing the rotor speed or stopping rotation of a wind turbine system.

Bypass Diode. A diode connected across one or more cells in the forward current direction to allow the module current to bypass shaded or broken cells to prevent hot spot or hot cell damage resulting from the reverse voltage biasing from the other cells in that module.

Conventional generation. Internal combustion engine-generator sets, and /or shaft generators (for the purpose of the use of this document).

Converter. A device that receives electrical energy with a set of input parameters and exports electrical energy with a different set of parameters.

Dead Ship Condition (Hybrid Power Systems). A condition under which

i) The main propulsion plant and auxiliary machinery are not in operation due to the loss of the main source of electrical power (i.e., battery, fuel cell or other hybrid energy plant).

ii) In restoring propulsion, the stored energy for starting the main source of electrical power and other essential auxiliary machinery are assumed to be unavailable.

iii) In restoring propulsion, the main source of electrical power and other essential auxiliary machinery are assumed to be unavailable.

Dead Ship Condition (All-Electric Power Systems). A condition under which

i) The main source of electrical power for propulsion of the vessel and operating auxiliary machinery are not in operation and

ii) the stored energy for starting the main source of electrical power and other essential auxiliary machinery are assumed to be unavailable.

Electrical Load Profile. A graph of the variation in the electrical load demand versus time. It is a representation of the power consumption of a system over a specific period of time.

Electric Vessel Connector. A device that, when electrically coupled (conductive or inductive) to an electric vessel inlet, establishes an electrical connection to the electric vessel for the purpose of power transfer and information exchange. It is part of the electric vessel coupler.

Electric Vessel Coupler. A mating electric vessel inlet and electric vessel connector set.

Electric Vessel Inlet. The device on the electric vessel into which the electric vessel connector is electrically coupled (conductive or inductive) for power transfer and information exchange. This device is part of the electric vessel coupler.

Energy Management System (EMS). A computerized control system designed to regulate the energy consumption of a vessel by controlling and monitoring the operation of energy storage systems, electrical loads and the production of power. The system can monitor environmental and system loads and adjust operations in order to optimize energy usage, and respond to demand conditions. For the purpose of this document the EMS can also have similar functionalities as a PMS.

Energy Storage System (ESS). A system composed of an energy storage transformation device, a converter (if necessary), controls, and ancillary components and equipment. It is capable of delivering/capturing electrical energy to/from a load at the required voltage and rate (power), and can accommodate the load rate of change of power.

Energy Transformation Device (ETD). A device that converts energy from one form to another. The source energy may be renewable or stored. The transformation may be unidirectional or bidirectional. A fuel cell is a type of ETD.

Flexible Photovoltaic Module. A photovoltaic module that is designed to be intentionally and repetitively twisted, curved or otherwise bent without physical, electrical or visual damage.

Fuel Cell. (FC). A source of electrical power in which the chemical energy of a fuel is converted directly into electrical and thermal energy by electrochemical oxidation.

Furling. For wind turbines, a passive control mechanism by means of reducing the projected swept area, which can be used to e.g., control the wind turbine system power or rotational speed, etc.

Horizontal Axis Wind Turbine. A wind turbine system whose rotor axis is substantially parallel to the wind flow.

Hot Spot. An intense localized heating in a PV module when its operating electric current exceeds the reduced short-circuit current of a shadowed or faulty PV cell or group of cells within it. When a hot spot occurs, the affected cell or group of cells is forced into reverse bias to dissipate power, which can cause overheating. The voltage bias or damage creates a small, localized shunt path where a large portion of the PV module current appears.

Hybrid Electric Power System. A system combining internal combustion engine driven generators and/or shaft generator/motor driven by main engine with an ESS consisting of batteries, supercapacitors, fuel cells, and/or other technologies to form the power generation and propulsion system of the vessel.

Integrated Electric Power System (IEPS). A system where a set of generators supply power to the vessel service loads as well as the propulsion loads. Sometimes it is also termed an integrated electric propulsion system.

Low Exhaust Emission (LEE) Mode. An operating mode when no internal combustion engine exhaust gas from the onboard sources of electric power is generated. The ESS and fuel cell power systems are examples of electric sources of power to feed loads in the ship's electrical power distribution system with near-zero exhaust emissions.

Main Source of Electrical Power: A source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the vessel in normal operational and habitable conditions.

Maximum Power Point Tracking (MPPT). A control strategy whereby PV array operation is always at or near the point on a PV device's current-voltage characteristic where the product of electric current and voltage yields the maximum electrical power under specified operating conditions.

Overspeed Control. The action of a wind turbine control system, or part of such system, which prevents excessive rotor speed.

Peak Shaving. Any of the various strategies to reduce main electric power generation during certain periods, and to store energy to supply the demand of electricity during other operating times. The goal is to store energy during periods of low power demand and release energy during high peaks of power demand (typically by the ESS).

Photovoltaic Array. A mechanical and electrical assembly of photovoltaic modules, photovoltaic panels or photovoltaic sub-arrays and its support structure.

Photovoltaic Module. A complete and environmentally protected assembly of interconnected photovoltaic cells.

Photovoltaic Module Junction Box. A closed or protected enclosure on a photovoltaic module in which circuits are electrically connected and where protection devices may be located if necessary.

Photovoltaic Panel. PV modules mechanically integrated, pre-assembled and electrically interconnected.

Photovoltaic String. A circuit of series-connected PV modules.

Photovoltaic System. An assembly of components that produce and supply electricity by the conversion of solar energy.

Pitching. Adjusting the angle of attack (blade pitch angle) of wind turbine blades, which can be used to control the wind turbine system power or rotational speed.

Power Backup (PBU) Mode. The operating mode where the energy storage system (ESS) is connected to the ship's electrical main or distribution system and is able to reliably provide power for a minimum period. This is also known as the spinning reserve mode. Operating a redundant diesel generator as spinning reserve provides power in a failure condition. Running an extra engine creates a less efficient, lower load condition with higher emissions. Providing this spinning reserve via stored energy, rather than an additional diesel generator, allows the electrical system to operate with fewer generators at higher load. The stored energy (lithium-ion batteries) provides power in the event of a loss of generator until a standby generator can be started and connected to the power system.

Power Conversion Equipment (PCE). An electrical device converting one kind of electrical power from a voltage or current source into another kind of electrical power with respect to voltage, current and frequency. Examples include AC-DC converters, DC-AC inverters, DC-DC charge controllers, frequency converters, etc.

Power Management System (PMS). A complete switchboard and generator control system which controls and monitors power generation and distribution including multiple switchboards and ring bus systems. The PMS on board a vessel is responsible for functions such as load sharing among different power sources, load shedding, and starting reserve generators when power is insufficient. For the purpose of this document the PMS can also have similar functionalities as an EMS.

Power Management (PMT) Mode. A mode designated when different load schedule strategies, functions, load control strategies such as load sharing and load shedding are met through the PMS installed on board the vessel or unit.

Power Take-In (PTI) Mode. A mode in which the shaft generator functions as an auxiliary motor working concurrently with the main diesel engine or independently for electric propulsion, also known as shaft motor mode. This mode provides propulsion power to the shaft which boosts the main engine with extra power or as an electric propulsion motor with the main engine clutched out or secured.

Power Take-Off (PTO) Mode. This operating mode takes the energy generated in the main engine as taken off by the shaft generator to produce electricity as an additional power source.

Rated Capacity. The capacity value of a cell or battery determined under specified conditions and declared by the manufacturer. [*IEC 62620*] Capacity is usually measured in Amp-hours (Ah).

SCADA System. A system operating with coded signals over communication channels to provide control of equipment and to acquire information about the status of the equipment for display or for recording functions.

Small Wind Turbine. A system of 200 m^2 rotor swept area or less that converts wind energy to electrical energy. A small wind turbine system includes the wind turbine itself, support structures, the turbine controller, the charge controller / inverter (if required), wiring and disconnects, the installation and operation manual(s) and other documentation.

Smart Function: Systems installed, and services deployed to continuously collect, transmit, manage, analyze, and report data for enhanced health and condition awareness, operational assistance, operational optimization, and decision-making support.

State of Charge (SOC). The available capacity in a battery expressed as a percentage of rated capacity. [*IEC 62660-1*]

Supplemental Source of Electric Power. Electric power generation or capacity supplied by an alternative source of power that is in addition to the vessel's main or emergency electric power generation (e.g., Solar or Wind, Battery, etc.). Supplemental electrical power is not to be included in the determination of the required number generators or capacity as referenced in 4-8-2/3.1 of the *Marine Vessel Rules*.

Support Structure. For photovoltaic equipment, support structure (also known as “racking”) is used to physically support modules or groups of modules and position them in a fixed or moving orientation relative to the path of the sun. For a wind turbine system, support structure comprises the tower and foundation.

Swept Area. For a wind turbine, the projected area perpendicular to the wind direction that a rotor will describe during one complete rotation.

Tracker. For solar PV systems, a mechanical device used to track or follow the sun across the sky on a daily basis. Standard PV trackers are used to minimize the angle of incidence between incoming light and a PV module. This increases the amount of energy produced from a fixed amount of power generating capacity.

Transitional Source of Power. An emergency source of power usually produced by diesel generators, gas turbine generators or steam turbine generators but can also be supplied by alternative sources such as electric batteries, super-capacitors, and fuel cells, specifically for use when transferring from one source of power to another, and intended to be provided for a specified, finite period of time.

Vertical Axis Wind Turbine. Wind turbine system whose rotor axis is substantially perpendicular to the wind flow.

Wind Turbine Generator System. Wind turbine system which converts kinetic energy in the wind into electrical energy.

Yawing. Rotation of the wind turbine rotor axis about a vertical axis (for horizontal axis wind turbines only).

Yaw Misalignment. Horizontal deviation of a wind turbine rotor axis from the wind direction.

9 Abbreviations and Acronyms *(1 April 2024)*

The following abbreviations and acronyms are applied to the terms used in this document:

ABS	American Bureau of Shipping
AUTO	Automation (Control, Monitoring and Safety Systems) Goal
BMS	Battery Management System
BoD	Basis of Design
CMS	Capacitor Management System
CONOPS	Concept of Operations
DPS	Dynamic Positioning System
EG	Emergency Generator
EMS	Energy Management System
ESS	Energy Storage System
ETD	Energy Transformation Device
ETS	Energy Transformation System
ESD	Emergency Shutdown
FC	Fuel Cell

FC-CMSS	Fuel Cell Control, Monitoring, Safety System
FC-PS	Fuel Cell Power System
GENSET	Diesel Generator or Generator together with Prime-mover
IEC	International Electrotechnical Commission
IEPS	Integrated Electric Power System
IC	Internal Combustion
LEE	Low exhaust Emission
MGMT	Safety Management Goal
NDT	*Nondestructive Testing*
OCC	Offshore Charging Connection
PBU	Power Backup
PEC/PCE	Power electronic converters/Power conversion equipment
PMS	Power Management System
PMT	Power Management
POW	Power generation and distribution Goal
PROP	Propulsion, Maneuvering and Station Keeping Goal
PTO	Power Take Off
PV	Photovoltaic
SAFE	Safety of Personnel Goal
SC	Supercapacitor
SCMS	Supercapacitor Management System
SCN	Shore Connection
SOC	State of Charge
SOLAS	*The International Convention on the* Safety of Life at Sea
UL	Underwriters Laboratories
UPS	Uninterruptible Power Systems

11 References

11.1 ABS *(1 April 2024)*

ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*

ABS *Rules for Building and Classing Mobile Offshore Units (MOU Rules)*

ABS *Rules for Building and Classing Single Point Mooring (SPM Rules)*

ABS *Rules for Building and Classing Yachts (Yacht Rules)*

ABS *Guide for Building and Classing Bottom-Founded Offshore Wind Turbines*

ABS *Guide for Building and Classing Floating Offshore Wind Turbines*

ABS *Guide for Smart Functions for Marine Vessels and Offshore Units*

ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications*

ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications*

ABS *Requirements for Use of Lithium-ion Batteries in the Marine and Offshore Industries (Lithium-ion Batteries Requirements)*

ABS *Requirements for Use of Supercapacitors in the Marine and Offshore Industries (Supercapacitor Requirements)*

ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*

ABS *Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification*

ABS *Guide for Dynamic Positioning Systems*

ABS *Guide for Comfort on Yachts*

ABS *Guide for Nondestructive Inspection*

ABS *Requirements for Wind Assisted Propulsion System Installation*

ABS *Guide for Crew Habitability*

11.3 IEC References *(1 April 2024)*

IEC 60079-10-1: *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60092-502: *Electrical Installations in Ships*

IEC 62619: *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Secondary Lithium Cells and Batteries, For Use in Industrial Applications*

IEC 62620: *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Secondary Lithium Cells and Batteries for Use in Industrial Applications*

IEC 62660 Series: *Secondary lithium-ion cells for the propulsion of electric road vehicles*

IEC 62391-1: *Fixed electric double-layer capacitors for use in electric and electronic equipment – Part 1: Generic specification*

IEC 62391-2: *Fixed electric double-layer capacitors for use in electronic equipment – Part 2: Sectional specification – Electric double layer capacitors for power application*

IEC 62391-2-1: *Fixed electric double-layer capacitors for use in electronic equipment – Part 2-1: Blank detail specification – Electric double-layer capacitors for power application – Assessment level EZ*

IEC 60812: *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 62576: *Electric double-layer capacitors for use in hybrid electric vehicles – Test methods for electrical characteristics*

IEC 62281: *Safety of primary and secondary lithium cells and batteries during transport*

IEC 62040-1: *Uninterruptible power systems (UPS) – Part 1-1: General and safety requirements for UPS used in operator access areas*

IEC 61800-5-1: *Adjustable speed electrical power drive systems: Safety Requirements – Electrical, thermal and energy*

IEC 60146-1-1: *Semiconductor converters – General requirements and line commutated converters – Specification of basic requirements*

IEC 60068-2-6: *Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)*

IEC 60068-2-52: *Environmental testing - Part 2-52: Tests - Test Kb: Salt mist, cyclic*

IEC 61215 Series: *Terrestrial photovoltaic (PV) modules - Design qualification and type approval*

IEC 61701: *Photovoltaic (PV) modules - Salt mist corrosion testing*

IEC 61730 Series: *Photovoltaic (PV) module safety qualification*

IEC TS 61836: *Solar photovoltaic energy systems - Terms, definitions and symbols*

IEC 62109 Series: *Safety of power converters for use in photovoltaic power systems*

IEC 62446 Series: *Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance*

IEC 62548: *Photovoltaic (PV) arrays - Design requirements*

IEC 62790: *Junction boxes for photovoltaic modules - Safety requirements and tests*

IEC 62817: *Photovoltaic systems - Design qualification of solar trackers*

IEC 61400-1: *Wind energy generation systems - Part 1: Design requirements*

IEC 61400-2: *Wind turbines - Part 2: Small wind turbines*

IEC 61400-11: *Wind turbines - Part 11: Acoustic noise measurement techniques*

IEC 61400-12-1*: Wind energy generation systems - Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC 61851: *Electric vehicle conductive charging system*

11.5 Other References *(1 February 2022)*

IMO *International Convention for the Safety of Life at Sea (SOLAS)*

ISO 23274-1*: Hybrid-electric road vehicles — Exhaust emissions and fuel consumption measurements*

IMO *International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)*

ISO 21984:2018: *Ships and marine technology. Guidelines for measurement, evaluation and reporting of vibration with regard to habitability on specific ships*

11.7 Alternative Standards *(1 April 2024)*

Hybrid and all-electric power systems may comply with the requirements of an alternative standard, in lieu of the specific requirements in this document, provided such standards being determined by ABS as not less effective. Where applicable, other criteria may be imposed by ABS in addition to those in the alternative standard to meet the intent of this document. In all cases, the hybrid and all-electric power systems are subject to design review, survey during construction, tests, and trials as applicable by ABS to verify compliance with the alternative standard.

13 Type Approval Program *(1 April 2024)*

Products that can be consistently manufactured to the same design and specification may be Type Approved under the ABS Type Approval Program. When approval of such products and components as part of the hybrid and/or all-electric power system is requested, applicants are to contact ABS for the approval process. For ABS Type Approval Program requirements, refer to 1-1-4/7.7, Appendix 1-1-A3, and Appendix 1-1-A4 of the ABS *Rules for Conditions of Classification (Part 1)*. See Section 2/Table 2 of this document and 4-1-1/Table 3C of the Yacht Rules for certification details. Alternative certification arrangements are also available in 1-1-A3/5.5 of the ABS *Rules for Conditions of Classification (Part 1A)*.

SECTION 2

Plans and Data to be Submitted for All Vessel Types (*1 April 2024*)

1 System Documents and Plans to be Submitted

1.1 General

1.1.1 Hybrid and Hybrid Ready (*1 April 2024*)

For **HYBRID and HYBRID Ready** vessels, documentation showing optimization calculations/ results for sizing the hybrid electric power system is to be submitted for review.

The combination can be conventional power generation[1, 2] and non-conventional power generation[3], or two or more non-conventional power generation.

i) Internal combustion engine (Diesel/ dual fuel/gas) driven electric generators [1]

ii) Power Take-Off (Shaft Generators) [1]

iii) Fuel cells or solar PV arrays or wind turbines

iv) Lithium-Ion battery banks or

v) Other stored energy (e.g., supercapacitors)

In addition to the plans, specifications, ship arrangements, test plans, and data required to be submitted to ABS for review and approval as listed in 4-8-1/5 of the *Marine Vessel Rules*, drawings and data outlined below are to be submitted to ABS for review, as applicable:

Notes:

1 Conventional generation: internal combustion engine driven generator sets, and /or shaft generators.

2 Internal combustion engine driven generator sets and shaft generators by themselves alone do not meet the criteria for **HYBRID**.

3 Non-conventional power generation can include low- or zero- emission power generation systems such as solar PV arrays or wind turbines.

1.1.2 All-Electric Power System (*1 April 2024*)

For **All-Electric** vessels using any combination of two or more of the non-conventional power sources, documentation showing optimization calculations and results for sizing the all-electric power system is to be submitted for review.

In addition to the plans, specifications, ship arrangements, test plans, and data required to be submitted to ABS for review and approval as listed in 4-8-1/5 of the *Marine Vessel Rules*, the drawings and data outlined below are to be submitted for review, as applicable.

1.3 HYBRID/All-Electric Vessel Submissions *(1 April 2024)*

The following plans, data, and specifications are to be submitted for review as applicable.

The following symbols are used in this section for the type of review of the documents:

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review

OB: Documentation which needs to be kept onboard

i) For general requirements for documentation related to battery power system design, see Subsection 1/9 of the ABS *Requirements for Use of Lithium-ion Batteries in the Marine and Offshore Industries (Lithium-ion Batteries Requirements)*.

ii) For general requirements for documentation related to supercapacitor power system design, see Subsection 1/13 of the ABS *Requirements for Use of Supercapacitors in the Marine and Offshore Industries (Supercapacitor Requirements)*.

iii) For general requirements for documentation related to fuel cell power system design, see Subsection 1/9 of the ABS *Requirements for Fuel Cell Power System for Marine and Offshore Applications (Fuel Cell Requirements)*.

iv) A description of the PMS, including location and arrangement plan.**(R)**

v) Arrangements, details, and location of the propulsion control consoles and or panels including schematic diagrams of the system therein.**(R)**

vi) Arrangements and details of the semiconductor converter enclosure for propulsion system, where applicable, including cooling system with its interlocking arrangement.**(R)**

vii) Risk assessment documentation (identifying risks associated with the design, installation, test and sea-trial/ commissioning, and safe operation of the electrical power system as new and conventional technologies are integrated on board). See also Subsection 3/17.**(R)**

viii) General Arrangement of power distribution system including energy storage system.**(R)**

ix) Fuel consumption data in various operating modes, as applicable, for record.**(OB)**

x) Calculations for sizing energy storage system (ESS), (e.g., battery selection, type and size, etc.). **(R)**

xi) Basis of design and or specifications of integration of control systems, EMS, PMS, BMS, SCMS, ESS, etc. **(R)**

xii) Electrical one line diagram of main and emergency power distribution systems to show **(R)**

- *a)* Power Source: kW rating, voltage, rated current, frequency, number of phases and power factor, type, battery charging and discharging boards where applicable.
- *b)* Motors: kW or hp rating, voltage and current rating, type
- *c)* Motor controllers: type (direct-on-line, star-delta, etc.), disconnect devices, overload and undervoltage protections and remote stops, as applicable
- *d)* Transformers: kVA rating, rated voltage and current, winding connections
- *e)* Circuits: designations, type and size of cables or bus bar, trip setting and rating of circuit protective devices, rated load of each branch circuit, emergency tripping and preferential tripping features

xiii) Short-Circuit Data **(R)**

- *a)* Maximum calculated short-circuit current values, both symmetrical and asymmetrical values, available at the main and emergency switchboards and the downstream distribution boards *b)* Rated breaking and making capacities of the protective devices

xiv) Schematic diagrams for the following systems are to be submitted. Each circuit in the diagrams is to indicate type and size of cable, trip setting and rating of circuit protective device, and rated capacity of the connected load **(R)**

a) Interior communications

b) General emergency alarm

c) Intrinsically safe systems

d) Fire detection and alarm system (if independent from vessel marine systems)

e) Schematics for DC power system as listed in Section 2/5 of ABS Requirements for DC Power Distribution Systems for Marine and Offshore Applications.

f) Plans and data related to vessels connecting to high voltage and low voltage shore connection as listed in 6-4-1/7 of the *Marine Vessel Rules* as applicable.

xv) Plans and data related to computer-based systems as listed in 4-9-1/7.3.9 of the *Marine Vessel Rules* as applicable.

xvi) Operations and maintenance manual that includes in service inspection plans for fuel cell and lithium-ion batteries, and/or other stored energy.**(I,OB)**

xvii) Test plans required for the testing listed in 7/1.7.1 i.**(R)**

xviii) Commissioning Test Plan required by 7/1.7.1 ii.**(R)**

xix) Fuel containment inspection plan required by 7/1.7.1 iii.**(R)**

xx) Operating Mode Trials Plan required by 7/1.7.1 iv.**(R)**

xxi) Emergency shutdown (ESD) arrangement.**(R)**

xxii) Load analysis and balance, covering all operating conditions of the vessel, such as normal seagoing, cargo handling, harbor maneuvering, dynamic positioning, emergency operation, peak shaving, zero-emission, and any other operating mode as applicable.**(R)**

xxiii) Ventilation arrangement of energy storage space including fire dampers, emergency shutdown from outside space.

xxiv) List of minimum alarms/displays and shutdowns as required in Section 3/Table 5.**(R)**

xxv) Description of the operating modes of the components, equipment and systems and specific parameter values during each mode of operation as well as during transition from one mode to another, and during fault conditions.**(R)**

xxvi) Details of piping system and components associated with the hybrid/all-electric/ESS systems, where applicable.**(R)**

xxvii) Manufacturer's recommendation regarding hybrid/all-electric power system equipment's service life and inspection cycles (e.g., ESS, fuel cells, etc.). It is to include in service inspection plans for fuel cell, lithium-ion batteries, and/or other stored energy. See 3/3.3.2.**(R)**

xxviii) Designer's documentation (e.g., estimation/calculations) regarding hybrid/all-electric power system equipment/system's integration service life (e.g., ESS, fuel cells, etc.) considering the overall configuration. It is to include in service inspection plans for fuel cell, lithium-ion batteries, and/or other stored energy. See 3/3.3.2.**(R)**

xxix) Modeling, simulation, and the detailed results are to be submitted as applicable for review as required in 3/23.**(R)**

a) Model of the hybrid/all-electric power system that has been developed in a simulation space that supports the functional mockup interface (FMI) standard.

b) Battery sizing simulation models and their results including description of electrical load profile as per 3/7.7

c) Report of the results of the execution of the simulation of the hybrid / all-electric power system model depicting steady state operation, switching operation, transient operation, and fault operation of the power system. The simulation results are to be provided in a format that allows comparison to simulations performed independently on alternative simulation software.

d) Short circuit analysis that may be part of the simulation above.

e) Power, energy, and load flow analysis that may be part of the simulation above.

f) Power quality analysis that may be part of the simulation above.

g) Protection scheme that includes a protective device coordination study that may be part of the simulation above.

xxx) A list/booklet identifying all electrical equipment installed in the hazardous areas, as applicable. **(R,OB)**

xxxi) List of subsystems/components that make up the hybrid/all-electric power system along with the details of the suppliers responsible for submitting drawings to ABS is to be provided by the System Integrator. The list is to be supported by ABS product design assessment (PDA) for the equipment/subsystems, as applicable. When unit certification is required for an equipment/ subsystem, corresponding ABS survey reports are to be made available to the attending Surveyor verifying the integration of the hybrid/all-electric power system.**(I)**

xxxii) All-Electric Vessel System Philosophy document to describe the propulsion, the sources of power, the mission, operating modes, length of voyages between charges, and reserve power capacity.**(I)**

xxxiii) Concept of Operation Document (CONOPS) **(R,I)**

It is acknowledged that in the implementation process, the CONOPS is an evolving document. A draft CONOPS is to be submitted at the beginning of the project.

This document is to include, as a minimum, the following:

a) Battery system design and sizing

b) Detailed stage by stage Fire Fighting Procedure

c) Specific time limit for EM operation as detailed in 3/5.3.2 Table 2

d) Documents relating to Safe Return to Designated Safe Area

- Safe area location, layout and details
- Sufficient energy to return to designated safe area
- Safe return to designated safe area assessment (to include vessel's description, essential systems, critical systems, methods and assumptions, manual actions, testing and maintenance plan, etc.)
- Onboard documentation submitted for file and reference, operational manual for casualty cases below and exceeding threshold, list of spaces with negligible fire risk, and test, inspection, and maintenance plan.

At the completion of the verification and validation phase, a final and comprehensive CONOPS is to be submitted for approval.

xxxiv) The recovery arrangement of starting from dead ship condition including duration, system design and the fuel preparation are to be documented and submitted to ABS for review.(R).

1.5 HYBRID/All-Electric Vessel [Operating Mode] Submissions *(1 April 2024)*

In addition to 2/1.3 above, a list of submission requirements for different operating modes is provided in 2/Table 1 below:

TABLE 1
Hybrid/All-Electric [Operating Mode] Submissions *(1 April 2024)*

	Submittal Item	*Operating Mode*	
		HYBRID [LEE], [PMT], [PBU], [PTO/PTI], [SCN], [OCC], [EM]	*ALL-Electric Vessel [PMT], [PBU], [SCN], [OCC]*
1	System arrangement and associated drawings and information	x	x
2	A list of any additional alarms, monitoring and safeguards	x	x
3	Overload and load shedding arrangement	x	x
4	Arrangements and details of shaft generator electric coupling/clutch	x	
5	Control strategy and detail arrangements for the interconnection of ESS, FC, SC, and conventional generators (including shaft generator)	x	
6	Descriptions of electrical system grounding philosophy	x	x
7	Short Circuit current calculations	x	x
8	Protection device coordination study	x	x
9	Total harmonic distortion calculation	x	x
10	Capacity rating of charging connection installation, including maximum design short-circuit level	x	x
11	IP rating, circuit breaker rating, socket rating and schematics	x	x
12	Details of transformer including kVA rating, impedance information and construction details	x	x
13	Descriptions of safety interlocks	x	x
14	Details of the cable management system, if installed	x	x
15	Equipment Locations	x	x

Note: "x" implies "Applicable".

1.7 HYBRID Ready/All-Electric Ready Notation Submissions *(1 April 2024)*

1.7.1 Ready 1C - Concept Design Review

The following plans and documentation are to be submitted for review:

i) A description of the power management system (PMS), including proposed location and arrangement plan.

ii) Proposed arrangements, details, and location of the propulsion control consoles and or panels including schematic diagrams of the system therein.

iii) Proposed arrangement and overall single line diagram of power distribution system including energy storage system.

iv) Load analysis and balance, covering all operating conditions of the vessel, such as normal seagoing, cargo handling, harbor maneuvering, dynamic positioning, emergency operation, peak shaving, zero-emission, and any other operating mode as applicable.

v) Risk assessment in accordance with 1D-A1-2/5 of the ABS *Rules for Conditions for Classification*.

1.7.2 Ready 2D - Detail Design Review

For **Ready 2D**, the below plans and documents are to be submitted:

i) Proposed arrangements and details of the semiconductor converter enclosure for propulsion system, where applicable, including cooling system with its interlocking arrangement.

ii) Risk assessment documentation (identifying risks associated with the design, installation, test and sea-trial/ commissioning, and safe operation of the electrical power system as new and conventional technologies are integrated on board). Refer to Subsection 3/15.

iii) Proposed arrangement and overall single line diagram of power distribution system including energy storage system.

iv) Basis of design and or specifications of integration of control systems, energy management system (EMS), power management system (PMS), battery management system (BMS), supercapacitor management system (SCMS), and energy storage system (ESS).

v) Electrical one line diagram and schematics of propulsion control system for power supply, circuit protection, alarm, monitoring, safety, and emergency shutdown systems including list of alarm and monitoring points.

vi) Load analysis and balance, covering all operating conditions of the vessel, such as normal seagoing, cargo handling, harbor maneuvering, dynamic positioning, emergency operation, peak shaving, zero-emission, and any other operating mode as applicable.

vii) Emergency shutdown arrangement.

viii) Description of the redundancy configuration.

ix) Details of the automatic control, monitoring, alarm and safety functions.

1.9 Yacht Submissions

i) 2/1.3 and 2/1.5 above as applicable.

ii) See also Subsection A2/3.

1.11 Solar Photovoltaic Electric Power Generation Submissions *(1 February 2022)*

i) 2/1.3 and 2/1.5 above as applicable.

ii) See additional submittal items in Subsection 5/3.

1.13 Wind Electric Power Generation Submissions *(1 February 2022)*

i) 2/1.3 and 2/1.5 above as applicable *ii)* See additional submittal items in Subsection 6/3.

3 Certification *(1 April 2024)*

Hybrid/All-Electric power systems are to be certified in accordance with 2/Table 2 below. These tables also provide the applicability of the certification requirements for certain equipment and components as referred to in applicable Sections of the *Marine Vessel Rules* and *MOU Rules*. See also notes under this Table.

TABLE 2
Hybrid/All-Electric Power System Certification(4) *(1 April 2024)*

System, Equipment, Component	*ABS Certification(1)*	*ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)*	*Reference*
Battery Chargers	Required	4/5	Section 2/Table 1 of *Lithium-ion Batteries Requirements*
Battery Management Systems	Required	4/5	Section 2/Table 1 of *Lithium-ion Batteries Requirements*
Battery System Components	Required	4/5	Section 2/Table 1 of *Lithium-ion Batteries Requirements*
Fuel Cell Control and Monitoring System	Required	4/5	Section 1/Table 3 of *Fuel Cell Requirements*
Fuel Cell Modules	Required	4/5	Section 1/Table 3 of *Fuel Cell Requirements*
Fuel Cell Power System	Required(5)	4/5	Section 1/Table 3 of *Fuel Cell Requirements*
Non-Sparking Fans		2	4-8-3/11 of *Marine Vessel Rules*
Other Electrical Equipment	Required	1/2/4/5	4-8-3, 4-1-1/Table 3, of *Marine Vessel Rules* as applicable
Other Rotating Machines	Required	1/2/4/5	4-8-3, 4-1-1/Table 3, of *Marine Vessel Rules* as applicable
Pipe, Valves and Fitting	Required (2)	1/2/4/5	4-6-1, 4-1-1/Table 6 of *Marine Vessel Rules,* as applicable
Power Transformers and Converters for High Voltage System	Required	5	4-8-5/3.7.5(e) of *Marine Vessel Rules*
Power Transformers for Essential Service and for Emergency Source Power and Converters of Low Voltage		1	4-8-3/7, 4-8-3/8 of *Marine Vessel Rules*

System, Equipment, Component	*ABS Certification*[1]	*ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)*	*Reference*
Propulsion Generators	Required	5	4-8-3/3, 4-1-1/Table 3, 4-8-5/5.17.5 of *Marine Vessel Rules*
Shaft Generators & Propulsion Motors [3]	Required	5	4-3-2/1.5, 4-8-3/3, 4-8-5/5.17.5 of *Marine Vessel Rules*
Solar PV Electric Power Generating Systems	Required[6]	See Note 3	Section 5/5.1 Table 1 of this document
Supercapacitor Cells/ Modules	Required	4/5	Section 2/Table 1 of *Supercapacitor Requirements*
Supercapacitor Chargers	Required	4/5	Section 2/Table 1 of *Supercapacitor Requirements*
Supercapacitor Converters	Required	2	Section 2/Table 1 of *Supercapacitor Requirements*
Supercapacitor Management Systems	Required	4/5	Section 2/Table 1 of *Supercapacitor Requirements*
Wind Electric Power Generating Systems	Required[6]	See Note 3	Section 6/5.1 Table 1 of this document

Notes:

1 ABS Certification means plan review, and surveyors' attendance during construction and after installation to verify that a vessel, structure, item of material, equipment or machinery is in compliance with the Rules, Guides, standards or other criteria of ABS and to the satisfaction of the attending Surveyor.

2 Where indicated as 'required' in 4-6-1/Table 2 of the *Marine Vessel Rules*, the piping component is to be certified by ABS. This involves design approval of the component, as applicable, and testing in accordance with the standard of compliance at the manufacturer's plant. Such components may also be accepted under the Type Approval Program.

3 Shaft generators/motors used for power take-off, power take-in (propulsion boosters), or similar equipment, rated 100 kW (135 hp) and above are to be designed, constructed and tested (for both functionalities if applicable) in accordance with the appropriate requirements of the *Marine Vessel Rules.*

4 For units which are designed to the *MOU Rules* corresponding requirements of the *MOU Rules* are to be applied.

5 Fuel cell power systems having a net electrical output of 100 kW or greater are required to be certified by ABS. (See Note 1). For fuel cell power systems having a net electrical output of less than 100 kW, the manufacturer is to certify the standard to which it is designed, fabricated and tested to, and to report the results of the tests conducted.

6 The equipment/system can be accepted based on the manufacturers' documentation and quality as required in the IEC standards (including Standard tests reports, Certification, etc.).

5 Onboard Documentation (OB, I) *(1 April 2024)*

5.1 General *(1 April 2024)*

The following documentation and data are to be kept on board for reference by the operator for system operation and troubleshooting, maintenance, repair, and safety.

i) Applicable documents/operation and maintenance manuals such as EMS, PMS, BMS, CMS, and FC-CMSS.

ii) Hybrid/All-Electric power system operations and maintenance manual that includes in service inspection plans for fuel cell and lithium-ion batteries and/or other stored energy.

iii) Hybrid/All-Eelectric power system functional test schedules that includes in service inspection plans for fuel cell and lithium-ion batteries, and/or other stored energy.

iv) Records of safety training of personnel for ships' handling systems, storage, and equipment associated with fuel cell, battery, supercapacitor, wind turbine, and solar PV system

v) Mitigating plans or control measures for adverse events in case of possible safety critical scenarios including fire and explosion

SECTION 3

System Design

1 Objective *(1 April 2024)*

1.1 Goals

The hybrid/all-electric power systems covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 1	Provide safe and reliable storage and supply of fuel/energy/power.
POW 2	Provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
PROP 1	Provide sufficient thrust/power to move or maneuver the vessel when required
PROP 2	Provide redundancy and/or reliability to maintain propulsion
AUTO 1	Perform its functions as intended and in a safe manner.
AUTO 2	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 5	Be provided with a safety system that will automatically lead machinery being controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or environment
AUTO 6	Independently perform different functions, such that a single failure in one system will not render the others inoperative.
COMM 2	Provided with means for internal communications

The Goals in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of hybrid/all-electric power systems are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution	
POW-FR1	provide sufficient power capacity and quantity to achieve continuity of power with at least one source of power in standby.
POW-FR2	provide starting arrangement for the restoration of propulsion.
POW-FR3(AUTO)	provide protection against overload, short circuit, earth-fault and overvoltage conditions and other hazards to prevent damage to equipment and maintain continuity of power to remaining circuits..
POW-FR4	provide means to manage loads such that blackouts are avoided, and power is always maintained to essential services and propulsion loads.
POW-FR5	electric equipment connected to the power system is to be capable of operating in the power quality envelope of the system without damage.
POW-FR6	provide safe and stable electrical distribution scheme for Alternating Current (AC) and Direct Current (DC) systems.
POW-FR7	design and size the ESS to operate without damage throughout its service life.
POW-FR8	electrical equipment is to be designed and constructed to withstand the marine environment and maximum design ambient temperature and stresses without any deterioration.
POW-FR9	provide enclosure with suitable degrees of protection against ingress of foreign objects and liquids based on the location of installation.
POW-FR10	apply fail-safe design for the electrical power system, control and safety systems to prevent a dangerous situation due to a single point failure.
POW-FR11	provide means to adjust parameters for effective operation of wireless power transfer system.
POW-FR12	provide means to prevent accidental detachment of charging cable.
POW-FR13	provide measures to mitigate excessive strain on the charging cable and charging connection.
POW-FR14	provide arrangement to prevent overheating of charging cable while charging.
Propulsion, Maneuvering, station Keeping (PROP)	
PROP-FR1	vessel is to have capability to maintain the vessel's station safely during charging from an offshore charging connections (OCC).
PROP-FR2	provide designs/arrangements that enable propulsion and steering to be available after a defined failure scenario.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	control systems are to be designed to achieve safe and effective operation.
AUTO-FR2	power and energy management systems are to be designed so that its failure does not affect the availability of power sources.
AUTO-FR3	provide visual and audible notification at a manned control station upon occurrence of fault/faults in the HEPS control, monitoring and safety systems.
AUTO-FR4	apply fail-safe design for all control systems, monitoring systems and safety systems to prevent dangerous situations due to a single point failure.
AUTO-FR5	system independence is to be applied to safety systems performing different functions. Failure of one function should not lead to the loss of other functions.
AUTO-FR6	circuit protection devices are to be able to withstand the prospective short circuit current values at the point of installation.

Functional Requirement No.	*Functional Requirements*
Communications (COMM)	
COMM-FR1(POW/ AUTO)	provide means of verbal and digital communication to allow safe and effective control of charging operations on the vessel

The Functional Requirements in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.3 Compliance

Hybrid/all-electric power systems are considered to comply with the Goals and Functional Requirements within the scope of Classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Design Principles and System Configuration *(1 April 2024)*

3.1 General *(1 April 2024)*

Hybrid electric power systems combine internal combustion engine driven generators and/or shaft generator/motor driven by main engine with an ESS consisting of batteries, supercapacitors, fuel cells, or other technologies to form the power generation and propulsion system of the vessel.

All-Electric power systems incorporate one or a combination of energy storage system (ESS) and/or energy transformation device (ETD), including other non-conventional sources of power {e.g., solar and wind (electric) power}.

The design, construction, installation testing and maintenance is to be in general in accordance with this document, the *Marine Vessel Rules,* the *MOU Rules,* or other ABS Guides applicable to the type of vessel or installation under consideration.

For vessels, required to comply with the International Convention for the Safety of Life at Sea (SOLAS), the applicable requirements are:

- Part 4, Chapter 8, Electrical Systems of the *Marine Vessel Rules*, as applicable
- Part 4, Chapter 9, Automation of the *Marine Vessel Rules,* as applicable
- Section 3/3.1, 4/3.1 and 4/3.3 of *ABS Requirements for Use of Lithium-ion Battery in the Marine and Offshore Industries.*

For non-SOLAS vessels, special consideration may be given by ABS subject to technical review and subject to the acceptance of the flag State.

For offshore units, the applicable Parts of the *MOU Rules* are:

- Part 4, Chapter 3, Electrical Installations

For yachts the applicable Parts of the *Yacht Rules* are:

- Part 4, Chapter 6, Electrical Installations
- Part 4, Chapter 7, Shipboard Automatic or Remote Control and Monitoring Systems

When an ESS is being proposed as an emergency source of electric power, the ESS is subject to ABS technical assessment and approval, provided all requirements of 4-8-2/5 of the *Marine Vessel Rules* are complied with as applicable.

3.3 Main Source of Electrical Power *(1 April 2024)*

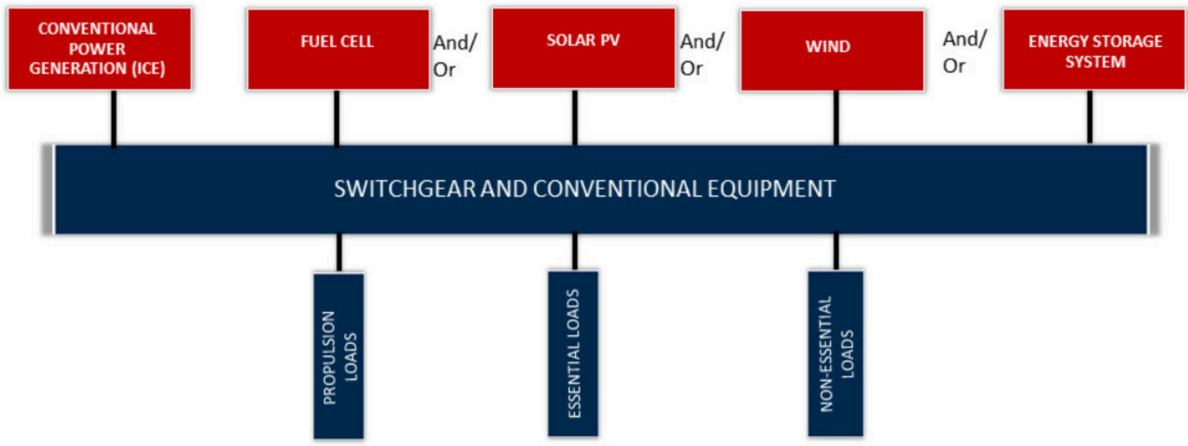
3.3.1 Integration of Different Technologies *(1 April 2024)*

Integration of different sources of power and the combination of these with different energy storage technologies are shown in the basic configuration, Section/Figure 1.

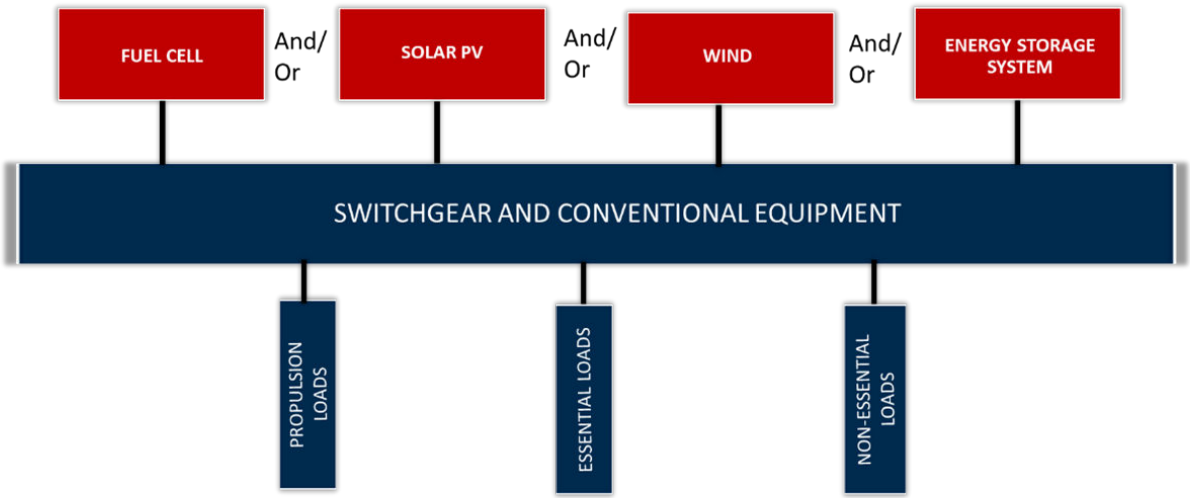
a) For Hybrid power systems, see the basic configuration in 3/3.3 Figure 1.

b) For All-Electric power systems, see the basic configuration in 3/3.3 Figure 2.

FIGURE 1
Integration of Different Sources of Power Generation and DrivenLoads for Hybrid



FIGUIRE 2
Integration of Different Sources of Power Generation and Driven Loads for All-Electric



3.3.2 Selection of Electric Source of Power and Energy Storage Systems for Hybrid *(1 April 2024)*

Different types of power generation and ESS sources contribute to the hybrid electric power system. These provide electrical power to the ship's service electrical loads and the electric motor driven propulsion loads of the vessel or unit. See 3/3.3 Figure 3.

The combination of hybrid electric power systems provides alternatives to conventional electrical plant configurations and allows vessel operators more options for optimizing the configuration to best serve the varied load profiles during different operating modes. See 3/5– Operating Modes.

The energy transformation devices (ETD) and the energy storage systems (ESS) are to be selected and sized to provide sufficient power capacity and quantity to achieve continuity for all operational modes of hybrid electric power system with any one energy source in reserve to carry:

- Those electrical loads for essential services and for minimum comfortable conditions of habitability, as defined in 4-8-1/7.3.3 and 4-8-1/7.3.4 of the *Marine Vessel Rules*, as applicable and
- The electrical loads related to the electric power critical notations listed in 4-8-1/7.3.6 of the *Marine Vessel Rules*.

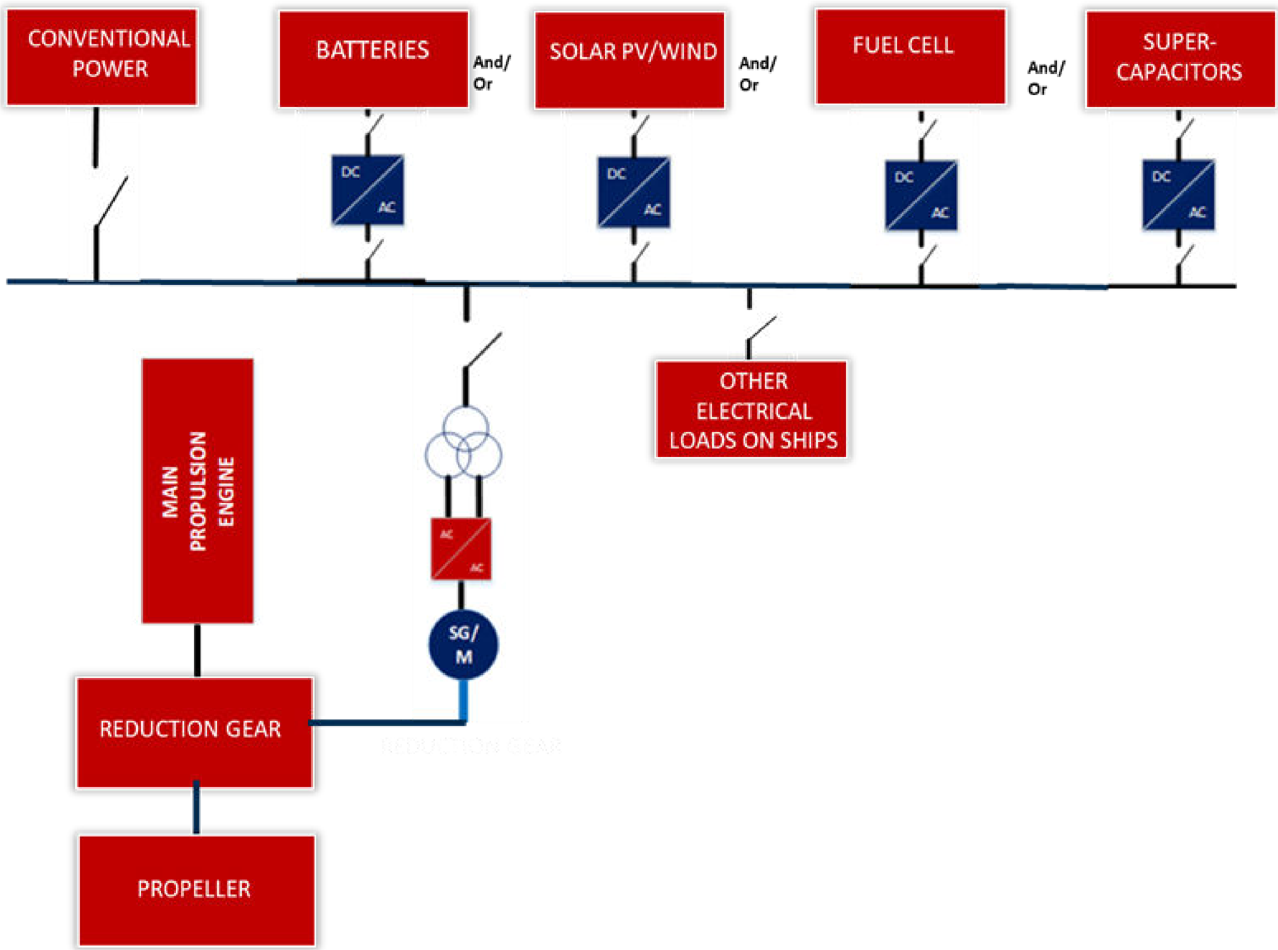
If the nature of the ESS is such that it will normally exhibit a loss of capacity or performance due to usage or age, the ESS is to be selected and sized based upon the capacity and performance of the ESS considering its capacity degradation over time.

For vessels installed with lithium-ion batteries, supercapacitors and/or fuel cell power system, the requirements as shown in Section 3/Table 1 are to be met as a minimum.

TABLE 1
Requirements for ESS/ETD *(1 February 2022)*

	Applicable System	*Reference*
ESS	Lithium-ion Batteries - Battery Management System (BMS)	ABS *Requirements for Use of Lithium-ion Batteries in the Marine and Offshore Industries*
	Supercapacitors - Capacitor Management System (CMS)	ABS *Requirements for Use of Supercapacitors in the Marine and Offshore Industries*
ETD	Fuel Cell Power System	ABS *Requirements for Fuel Cell Power System for Marine and Offshore Applications*
	Solar PV Electric Power Generation System	See Section 5
	Wind Electric Power Generation System	See Section 6

FIGURE 3
Combination of Different Types of Power Generation, Energy Sources, and Driven Loads for Hybrid *(1 April 2024)*



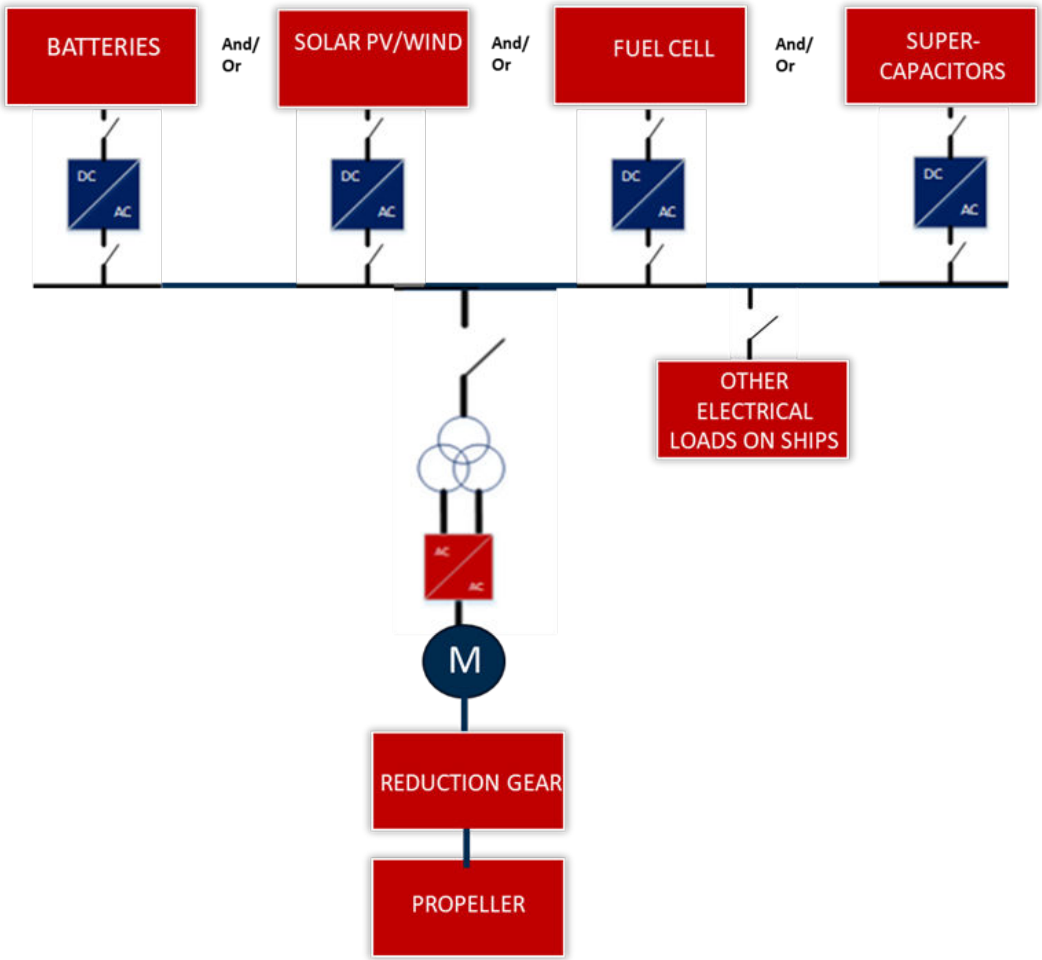
3.3.3 Selection of Electric Source of Power and Energy Storage Systems for All-Electric *(1 April 2024)*

One or a combination of energy storage system (ESS) and/or energy transformation device (ETD), including other non-conventional sources of power contribute to all-electric power system. These provide electrical power to the vessel's service electrical loads and the electric motor driven propulsion loads of the vessel or unit. See 3/3.3 Figure 4.

When all the main sources of power are based on ESS only, the main source of power consists of at least two independent ESS systems located in two separate ESS spaces.

For vessels installed with lithium-ion batteries, supercapacitors and/or fuel cell power systems, the requirements as shown in 3/Table 1 are to be met as a minimum.

FIGURE 4
Combination of Different Types of Power Generation, Energy Sources, and Driven Loads for All-Electric



3.3.4 Consideration for Motor Starting Current *(1 April 2024)*

In selecting the capacity of the power source(s), particular attention is to be given to the starting current of the motors in the system. With any one or a combination of power source(s) held in reserve as a standby, the remaining power source(s) operating in parallel and initially carrying the loads in 7/3.7, are to have sufficient capacity with respect to the largest idle essential motor on the vessel so that the motor can be started and the voltage drop occasioned by its starting current will not cause any already running motor(s) to stall or control equipment to drop out. The limits of transient voltage variation under suddenly applied loads are to be in accordance with 4-8-3/3.13.2(c) of the Marine Vessel Rules.

For vessels fitted with electric motor driven athwartship thrusters to assist maneuvering, the starting and running of this motor may be supported by all the installed power source(s), provided arrangements are made such that its starting is conditional upon the requisite power source(s) being available and that it will not cause inadvertent load shedding.

3.3.5 Main Switchboard *(1 April 2024)*

Where the main source of electrical power is necessary for propulsion of the vessel, the main bus bar is to be subdivided into at least two sections which are normally to be connected by circuit breakers or other approved means; so far as is practicable, the connection of power source(s) and other duplicated equipment are to be equally divided between the sections.

If the arrangement is such that the main switchboard is divided into separate sections which are interconnected by cable, the cable is to be protected at each end against faults.

"Other approved means" can be achieved by:

Circuit breaker without tripping mechanism; or disconnecting link or switch by which bus bars can be split easily and safely. Bolted links, for example bolted busbar sections, are not accepted.

3.3.6 Starting from Dead Ship Condition *(1 April 2024)*

Where electrical power is necessary to restore propulsion, the capacity is to be sufficient to restore propulsion to the vessel in conjunction with other machinery, as appropriate, from a dead ship condition within thirty minutes, as defined in 1/7.

Commentary:

Dead ship starting arrangements vary according to the concept of operations and technology used. Operational methods such as maintaining minimum battery level for return to designated safe area are subject to case-by-case approval by ABS and Flag Administration.

End of commentary

5 Operating Modes

5.1 General *(1 April 2024)*

The operational requirements of the hybrid and all-electric power systems are defined at the beginning of the design process; allocating space, weight, loading profile for the equipment and systems that will be installed during construction and operated during the service life of the vessel. The basis of design and specifications should be utilized to develop the load analysis and energy/power balance so that requirements for the elements and components of the hybrid and all-electric power system may be developed.

The basis of design, specifications and operational plan manuals are to include the plans and data describing all the subsystems integrated, and all the operating modes the vessel is designed for. Clear identification of parameter values during each mode of operation as well as during transition from one mode to another are to be included.

The applicable operation mode notations offered are listed in 3/Table 2 and Table 3.

Expected fault conditions and mitigation plans are to be identified during the risk analysis phase of the project and included in accordance with Subsection 3/17.

5.3 Operating Modes Capabilities

5.3.1 General

This section identifies and lists the different operating modes and their functionalities and arrangements needed for the vessel to be awarded the specific **HYBRID [operating mode]** notation.

The operating modes being applied for such notations are to be requested and specified on the submitted plan.

5.3.2 Key Operating Modes and Functionalities

The following table defines the different key operating modes referenced to the applicable notation offered by ABS for the hybrid electric power system installed on board and their functionalities and arrangements.

TABLE 2
Hybrid Operating Modes (1) *(1 April 2024)*

	Operating Mode	*Functionalities / Arrangements*	*Notation*
1	Low Exhaust Emission	1. Electrical power supplies the ship's consumers and main propulsion system by ESS and/or FC-PS 2. Engine driven gensets are off (e.g., at Port) 3. Boilers and incinerators operating on liquid fuel are to be off (e.g., at Port) 4. Specific time limit (vessel operating on ESS) is to be specified.	**HYBRID [LEE]**
2	Power Management	1. Typical schedule strategies: 1.1 Peak Shaving 1.2 Load Leveling/load smoothing 2. Load sharing control 3. Load shedding/preferential trips 4. Blackout prevention 5. The PMS is to be able to bring online all available generating sources (or ETS) after a blackout and to connect them to the electrical network.	**HYBRID [PMT]**
3	Power Backup	1. The ESS is to be readily available to the ship's electrical system during a contingency (e.g., loss of a conventional generator). 2. The ESS is to be connected to the main bus or distribution system in a specified time (e.g., in the order of seconds) that maintains the systems' stability. 3. The ESS is capable to provide power backup during certain time (e.g., during failures of the conventional power generation system). The power backup mode is also known as spinning reserve mode.	**HYBRID [PBU]**
4	PTO/PTI(2)	1. Power Take Off (PTO): Operating mode where a shaft generator provides electrical power flow to the ship's electrical network. 2. Power Take In (PTI): Operating mode where a shaft generator operates as a motor to boost the main propulsion engine power.	**HYBRID [PTO/ PTI]**

	Operating Mode	Functionalities / Arrangements	Notation
5	Shore Connection [3]	1. When the vessel is provided with a shore connection installation in accordance with Part 6 Chapter 4 of the *Marine Vessel Rules*. 2. The modes of operation related to the shore connection and hybrid is: ***i)*** The shore connection is arranged for charging the on board ESS while providing power to the vessel's electrical consumers, And/or ***ii)*** The on board ESS is arranged to provide power to some of the vessel's electrical consumers, while the shore connection provides electrical power to other electrical consumers on the vessel (configuration of electrical distribution system is to be monitored, with alarms, to prevent hidden failure when shore power is disconnected). 3. Operation of the vessel while connected to shore power by reducing onboard power generation, emissions, and local noise. (e.g., all combustion engines/gensets not operating).	**HYBRID [SCN]**
6	Offshore Charging Connection	1. When the vessel is provided with facilities to enable connection to an offshore charging station in accordance with Part 4, Chapter 5 of *ABS Rules for Building and Classing Single Point Moorings* and 3/35.3 and 3/35.5 of this document. 2. The modes of operation related to an offshore connection and hybrid is: ***i)*** The offshore connection is arranged for charging the vessel's onboard ESS while the vessel is connected to an offshore charging station in accordance with *ABS Rules for Building and Classing Single Point Moorings.* ***ii)*** Operation of the vessel is to be possible while connected to an offshore charging station by an energy source that is not being charged during this operation.	**HYBRID [OCC]**
7	Electric Mode	1. Electrical power supplies the ship's consumers and main propulsion system by ESS and/or FC-PS and/or any other non-conventional power source. 2. Specific time minimum requirement: ***i)*** a minimum of 1 hour for non-SOLAS vessels ***ii)*** a minimum of 3 hours for SOLAS vessels while operating on ESS and/or FC-PS and/or any other non-conventional power source is to be specified. Commentary: *Alternate times to the minimum specific time limit stated above may be considered with supporting documentation based on the type and operation of the vessel. The actual time for EM operation is to be indicated in the CONOPS document*	**HYBRID [EM]**

Notes:

1 All modes of operation are to be defined by the owner, designer, and or integrator.

2 Internal combustion engine driven generator sets and shaft generators by themselves do not meet the criteria for HYBRID.

3 Some other conditions may be required by specific Ports/local Administrations regarding the vessel operating at berth.

Each ESS, Genset (including a shaft generator) and converters are to be capable of delivering/ absorbing energy at the required rate to meet the power quality requirements (as specified for the project). For each operating mode, the following is to be specified:

- Energy/Power required
- Duty ratings
- Permissible load based on the load analysis calculation
- Lead (master) ESS or Genset, base loading as applicable
- Programmed kW/kVA load sharing between ESS and Genset(s) as defined by the power management strategy.

5.3.3 Key Operating Modes and Functionalities for All-Electric Vessel *(1 April 2024)*

The following table defines the different key operating modes referenced to the applicable notation offered by ABS for the all-electric power system installed on board and their functionalities and arrangements.

TABLE 3
All-Electric Vessel Operating Modes [1]

	Operating Mode	*Functionalities / Arrangements*	*Notation*
1	Power Management	1. Load sharing 2. Load shedding/preferential trips 3. Blackout prevention 4. The PMS is to be able to bring online all available power sources (or ETS) after a blackout and to connect them to the electrical network.	**All-Electric Vessel [PMT]**
2	Power Backup	1. The ESS is to be readily available to the ship's electrical system during a contingency (e.g., loss of main power source). 2. The ESS is to be connected to the main bus or distribution system in a specified time (e.g., in the order of seconds) that maintains systems' stability. 3. The ESS is capable to provide power backup during certain time (e.g., during failures of the other non-conventional power generation system). The power backup mode is also known as spinning reserve mode.	**All-Electric Vessel [PBU]**

	Operating Mode	*Functionalities / Arrangements*	*Notation*
3	Shore Connection [(2)]	1. When the vessel is provided with a shore connection installation in accordance with Part 6 Chapter 4 of the *Marine Vessel Rules* and 3/35.3 and 3/35.5 of this document. 2. The modes of operation related to the shore connection and all-electric vessel is: ***i)*** The shore connection is arranged for charging the on board ESS while providing power to the vessel's electrical consumers, And/or ***ii)*** The on board ESS is arranged to provide power to some of the vessel's electrical consumers, while the shore connection provides electrical power to other electrical consumers on the vessel (configuration of electrical distribution system is to be monitored, with alarms, to prevent hidden failure when shore power is disconnected).	**All-Electric Vessel [SCN]**
4	Offshore Charging Connection	1. When the vessel is provided with facilities to enable connection to an offshore charging station in accordance with Part 4, Chapter 5 of *ABS Rules for Building and Classing Single Point Moorings* and 3/35.3 and 3/35.5 of this document. 2. The modes of operation related to an offshore connection and all-electric vessel is: ***i)*** The offshore connection is arranged for charging the vessel's onboard ESS while the vessel is connected to an offshore charging station in accordance with *ABS Rules for Building and Classing Single Point Moorings.* ***ii)*** Operation of the vessel is to be possible while connected to an offshore charging station by an energy source that is not being charged during this operation.	**All-Electric Vessel [OCC]**

Notes:

1 All modes of operation are to be defined by the owner, designer, and or integrator.

2 Some other conditions may be required by specific Ports/local Administrations regarding the vessel operating at berth.

5.3.4 Power Management System Functionalities *(1 April 2024)*

i) *General*

A PMS is to be provided in accordance with applicable Sections of Part 4 of the *Marine Vessel Rules*, and applicable ABS Guides or ABS Requirements Documents.

ii) *Power Take Off / Power Take In (PTO/PTI) Functionality*

For vessels using combination of any internal combustion engine driven generator (and a shaft driven motor/generator {PTO/PTI}), and an energy storage system, and/or fuel cells, the fuel consumption and emissions optimization and calculation process for sizing the hybrid electric power system (propulsion system and electric power supply system) are to be submitted to ABS for review. Consideration is to be given to maximum values of sudden loads, (e.g., during changes of operating modes), and it is to be based on starting conditions and the PMS arrangements.

When it is intended that two or more shaft generators be operating in parallel, 4-8-3/3.13.3 of the *Marine Vessel Rules* is also to be complied with.

iii) *Peak-Shaving Functionality*

a) For vessels looking for a power management operating mode (PMT) and using a load management strategy as peak-shaving, the energy storage systems (ESS) is to be designed to provide sufficient electric power for the vessel's operation during a predefined period of time. The ESS capacity and such a time duration are to be identified in the basis of design (BoD) documentation.

b) Since there are several ways to peak shave, the designer/integrator is to indicate the strategy used for reducing consumption (e.g., by turning off non-essential equipment during peak hours and by the use of automatic load shedding/sharing mechanism to help reduce consumption (e.g., through the PMS)).

c) Load fluctuations to the power system are to be limited to the threshold as defined in the project's Basis of Design (BoD), and demonstrated by calculations, analysis, and simulation as appropriate.

7 Power Distribution System

7.1 Power Quality *(1 April 2024)*

i) Electrical power quality of the hybrid electric power system/ all-electric power system is to be maintained within the requirements of the applicable Rules and the standards to which the electrical power system, the components, and the equipment from which the electrical power system is constructed. In addition, consideration is to be given to the power quality requirements of consumers and appliances that are connected to and exchange energy with the power system. The requirements are specified in the *Marine Vessel Rules*:

Part 4, Chapter 8, Electrical Systems

- 4-8-2/7.21 - Harmonics
- 4-8-3/1.9 - Voltage/Frequency Variations

ii) Where power quality operating characteristics are outside of the above limits, the electric equipment connected to the power system is to be verified as being capable of operating in the expanded power quality envelope without damage. This is typically found during a hybrid electric power system/ all-electric power system integration's modeling and simulation process prior to system/equipment installation, the results from this process are to be submitted to ABS for review.

7.3 DC Power Distribution System *(1 April 2024)*

For Direct Current (DC) power distribution systems, see the ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications* for supplemental requirements, in addition to these:

i) All connected devices to the DC distribution system are to be able to operate normally under any operating conditions with the actual voltage, current amplitudes and frequencies generated by the inverter system.

ii) Each connected circuit to the DC distribution system is to have a suitable breaker or fuses and disconnect to:

a) isolate the zone in which a fault occurs in the event of a fault.

b) isolate a circuit for maintenance work.

iii) In case of fault in an inverter, a separate protective device is required to safely isolate the faulty circuit and maintain the operation of the DC distribution system without tripping other connected circuits. The protective devices may be fuses, DC breakers or semiconductor breakers. Semiconductor breakers are to be provided with disconnectors or other means to provide physical isolation of the circuits.

7.5 ESS Categorization based on Usage *(1 April 2024)*

The ESS can be used to serve essential loads (including emergency loads) and non-essential loads in accordance with *Marine Vessel Rules* and *MOU Rules*.

i) *Essential Service*. The ESS can be used for the purpose of feeding essential service loads as defined in 4-8-1/7.3.3 of the *Marine Vessel Rules*, and 4-1-1/3.5 of the *MOU Rules*.

ii) *Non-Essential Service*. The ESS can also be used for the purpose of feeding non-essential services.

The ESS is to be sized and selected accordingly to operate and provide functionality without damage, effect or degradation throughout its service life. See 3/1.5.1. Also see the specific requirements of the applicable ABS Guide or ABS Requirements Document.

7.7 Load Analysis and Battery Sizing *(1 April 2024)*

7.7.1 Load Analysis

For all-electric vessels, electrical load analysis is to cover all operating conditions of the vessel, such as normal sea going, cargo handling, harbor maneuver, emergency, and dynamic positioning.

The analyses are to include:

i) The simultaneous operation of loads on the emergency switchboard as per 4-8-2/5.5. Where the emergency power capacity is less than the sum of all the nameplate rated loads, which can be simultaneously connected to the emergency switchboard, then the analysis is to be supported by a justification for each reduced or non-simultaneous load used.

ii) High/low voltage ship service transformers or converters, where applicable per 4-8-2/3.7 *of the Marine Vessel Rules.*showing they have sufficient capacity to support the connected loads.

iii) Identification of the loads to be tripped to enable continuity of supply per 4-8-2/3.5.2.iii, 4-8-2/3.11.1, 4-8-2/9.1, 4-8-2/9.9 *of the Marine Vessel Rules.*

7.7.2 Battery Sizing

Battery system sizing, capacity calculation, and electrical load profile requirements are to comply with 4/3.3 of *Lithium-ion Batteries Requirements.*

The battery size is to be designed to have a safety margin in the depth of discharge of the battery system. This safety margin is to be supported in the CONOPS, which takes into account the operational environment and additional power demand due to electrical losses, vessel logistics, and operations.

9 Control and Instrumentation

9.1 General *(1 April 2024)*

The hybrid/all-electric power system's control system as referred to in this Section may be connected to an integrated control system or be a stand-alone system. It is to be designed for automatic operation and equipped with all the monitoring and control facilities required for safe operation of the system.

Integrated automation systems are to be designed to achieve safe and effective operation in accordance with the applicable Section 4-9-4 of the *Marine Vessel Rules*.

Redundancy criteria is to be considered, as applicable, in accordance with the applicable sections of the *Marine Vessel Rules,* the *MOU Rules,* or other ABS Guides, or Requirements Documents as appropriate for the type of vessel or installation under consideration. See references in 1/1.11.

9.3 Power Management System (PMS)

For power management system and functionalities, see 3/5.3.4.

Upon failure of the power management system, there is to be no change in the available electrical power. Failure of the power management system is to be alarmed at a manned control station. See also 3/Table 5.

9.5 Energy Management System (EMS) *(1 April 2024)*

i) General

The hybrid/ all-electric vessels typically have power systems and energy management control systems. The energy management control system is built with an operation strategy to control and supervise the different subsystems the hybrid / all-electric power system vessel is integrated with. The EMS will have several functionalities to supply, schedule, optimize (minimize/maximize) and interact with different energy transformation device's and/or energy storage's management systems.

The energy management system may consist of monitor(s), communications equipment, controller(s), timer(s), or other device(s) that monitors and/or controls electrical loads, power production and or storage sources.

Automatic control systems are to be designed to achieve safe and effective operation in accordance with the applicable Section 4-9-3 of the *Marine Vessel Rules*.

ii) EMS and Interaction with ETD's and ESS' Management Systems

The energy management system is to consider interfaces with other system such as PMS, BMS, CMS and FC-CMSS, etc. Section 3/Table 4 refers to the applicable management technologies as per ABS Rules, Guides and Requirements Documents.

TABLE 4
Energy/ Power Management Systems *(1 April 2024)*

Example of ESS, ETD Management Systems	*Reference*
Battery Management System (BMS)	2/1.3, Subsection 3/1 of *Lithium-ion Batteries Requirements*
Supercapacitor Management System (CMS)	Subsection 2/7, 3/1.5 of *Supercapacitor Requirements*
Fuel Cell Control, Monitoring and Safety System (FC-CMSS)	Section 6 of *Fuel Cell Requirements*
Power Management System (PMS)	4-8-5/5.3.3 of *Marine Vessel Rules*, *Dynamic Positioning System Guide*

The following functions are to be considered during the EMS operation strategy, as a minimum:

- Control and monitoring Energy Storage System (ESS).
- Monitoring Battery, Supercapacitor, Fuel Cell Power System.
- Supervision of load sharing between ESS and other generators.

- Maintain energy supply to the essential service loads and propulsion loads, as applicable.
- Failure of the energy management system is to be alarmed at a manned control station, alarms and safeguards are to be fitted in accordance with 3/Table 5.
- Upon failure of the energy management system, the available electrical power is to remain unchanged. Failure of the energy management system is to be alarmed at a manned control station.

9.7 Control, Monitoring, Alarm and Safety Systems *(1 April 2024)*

i) The hybrid/all-electric power system is to be monitored and provided with audible and visual alarms as a minimum in a normally attended location, such as the following spaces, as applicable:

a) Vessel's navigation bridge (or offshore manned control station) , or

b) Engine control room (or offshore propulsion centralized control station), or

c) Cargo control room

ii) Control, monitoring, and safety systems are to have self-monitoring facilities. In the event of failure to the systems or power supply, an alarm is to be activated.

iii) The safety system is to be designed such that failure of any of the system's components will not cause unsafe operation of the system or the equipment.

iv) Sensors for safety functions are to be independent from sensors used for other purposes (e.g., for alarm system).

v) The sensors are to be designed to withstand the local environment. The enclosure of the sensor and the cable entry are to be in accordance with the applicable sections of the *Marine Vessel Rules* and *MOU Rules*, for the space in which they are located.

vi) A list of monitored parameters, as a minimum, for alarm and shutdown is provided in Section 3/ Table 5 below.

TABLE 5
List of Alarms and Shutdown (1 April 2024)

Systems	*Monitored Parameters*		*A & D*	*Auto Shut down* (1)	*Notes [A = Alarm; D = Display; x = applies]*
Energy Storage System(3)(4)	A1	State of Charge (SOC) – low	x		
	A2	Charging/Discharging - failure	x	x	
	A3	Current – high	x	x	
	A4	Overload	x	x	
	A5	Voltage – high and low	x	x	
	A6	Frequency – high and low (only AC systems) (5)	x	x	
	A7	Cooling or fan - failure	x	x	
	A8	Emergency Stop (2)	x	x	See 7/1.7.1 iv)
	B1	Cooling medium pressure – low or, temperature – high	x		For subsystem having a cooling system.
	B2	Ventilation - failure	x	x	For subsystem having a ventilation system
	B3	Transformer - failure	x	x	For subsystem having a transformer
	B4	Converter - failure	x	x	For subsystem having a converter
	B5	ESS room or space – high ambient temperature	x		
	B6	ESS (cell, module) – high temperature	x	x	Alternative arrangements can be accepted on risk assessment basis
Shaft Generator	C1	Shaft Generator -failure	x	x	See 4/3.5
Energy Management System (EMS)	D1	Failure System	x		See 3/Table 4
Battery Management System (BMS)	D2	Failure System	x		See 3/Table 4, if fitted
Supercapacitor Management Systems (CMS)	D3	Failure System	x		See 3/Table 4, if fitted
Fuel Cell Control, Monitoring and Safety Systems (FC-CMSS)	D4	Failure System	x	x	See 3/Table 4, if fitted
Power Management System (PMS)	D5	Failure System	x		See 3/Table 4, if fitted

Systems	*Monitored Parameters*		*A & D*	*Auto Shut down* [1]	*Notes [A = Alarm; D = Display; x = applies]*
Wind Turbine Electrical Generation System	E1	Emergency Stop[6]	x	x	See 6/9.9.2
Solar PV Electric Power Generation System	F1	Current – high (including Hot Spots)	x	x	See 5/9.9.1
	F2	Control and Instrumentation	As per IEC	As per IEC	See 5/9.7

Notes:

1 An arrangement is made for starting a standby generator (or energy source) and connecting it to the switchboard, in accordance with 4-8-2/3.11 of the *Marine Vessel Rules* to prevent loss of power.

2 The emergency stop circuit is to be hard-wired and independent of any control system signal.

3 Grouped alarms may be allowed. Refer to the specific ABS Requirements (*Lithium-ion Battery or Supercapacitor*).

4 The ESS room or space is to be installed with appropriate means to vent gases which may be generated during an abnormal situation from the battery space to open deck.

5 The high and low frequency trip settings are to be defined and applied in accordance with the designer's and manufacturer's instructions/recommendations.

6 The emergency stop procedure for wind turbine power generation systems includes automatic stopping arrangements for extreme conditions, and any associated locks or release systems for blade control.

9.11 Remote Control Functions *(1 April 2024)*

Hybrid/all-electric vessels fitted with Remote Control Functions as defined in 1/7 are to comply with ABS *Requirements for Autonomous and Remote Control Functions* as applicable.

9.13 Computer Based Systems *(1 April 2024)*

Computer based systems (CBSs) including supervisory control and data acquisition (SCADA) systems when fitted to hybrid/all-electric vessels which provide control, alarm, monitoring, safety, or internal communication functions are to comply with the provisions of Section 4-9-3 of the *Marine Vessel Rules* as applicable.

9.15 Cyber Resilience *(1 April 2024)*

The Cyber Resilience requirements in Sections 4-9-13 and 4-9-14 of the *Marine Vessel Rules* are to be complied with, as applicable.

9.17 Smart Functions *(1 April 2024)*

Hybrid/all-electric vessels fitted with Smart functions as defined in 1/7 may comply with ABS *Guide for Smart Functions for Marine Vessels and Offshore Units* as applicable.

11 Electrical Protection System *(1 April 2024)*

The system protection requirements for hybrid/all-electric power systems are to comply with 4-8-2/9 of the *Marine Vessel Rules*, 4-3-2/9.11 of *MOU Rules* or 3/15 of the *ABS Requirements for DC Power Distribution Systems as applicable.*

Also, specific protection requirements for each technology can be found in the applicable ABS Guide or ABS Requirements Document.

Protection against fault conditions (e.g., short circuits) are also to take into account the following:

i) For protection zones defined by power electronic converters (PEC), the ABS *Requirements for DC Power Distribution System* can be used as reference. Other protection methods will also be acceptable provided coordination and selectivity is achieved.

ii) Due to different converter configurations used in AC and DC distribution systems, methods of calculating fault currents and protection coordination methodologies are to be based on steady and transient states as needed. Application of standards and/or other modeling and simulation approaches are to be documented and submitted to ABS for review.

Operational tests are to be carried out including but not limited to the testing of protective devices (over current, under-voltage, and preferential tripping, etc.), electrical interlocks, synchronization of generators, ESS and other alternative generating sources. See also 4-8-3/5.11.4 of the *Marine Vessel Rules*.

13 Equipment Earthing

Protection against electrical shock, exposed metal parts of electrical equipment earthing requirements are to be in accordance with 4-8-4/23 of the *Marine Vessel Rules*.

15 Degree of Protection

Enclosures and assemblies are to be constructed of steel or other suitable incombustible, moisture resistant materials and reinforced as necessary to withstand the mechanical, electro-magnetic and thermal stresses which may be encountered under both normal and fault conditions. Enclosures are to be of the closed type. The degree of protection of the enclosure is to be in accordance with the applicable requirements as per 4-8-3/Table 2, and 4-8-4/1.3 of the *Marine Vessel Rules*.

17 Risk Assessment *(1 April 2024)*

17.1 General *(1 April 2024)*

i) A risk assessment is to be conducted to identify risks associated with the design, installation and safe operation of the electrical power system as new and conventional technologies are integrated on board. The risk assessment is to demonstrate the vessel's safety and the continuity of power supply in case of failure of any part of the system. The risks are to be analyzed using acceptable and recognized risk analysis techniques.

ii) Loss of function, component damage, fire, explosion, and electric shock are to be considered as a minimum. The analysis should identify risks that can be eliminated wherever possible.

iii) Risks which cannot be eliminated are to be mitigated, as necessary. Identification of risks, and means by which they are mitigated, are to be documented to the satisfaction of ABS and to the flag Administration if required.

iv) Properly performed studies done early in the design process to identify hazards, risks and failure modes and allow for them to be resolved, and to enhance safety and performance are to be included. Consideration is to be given to aligning these studies with modeling and simulation efforts.

v) The risk assessment is to demonstrate that in the event of any single failure in the steering gear, control system or power supply, the vessel's steering and propulsion are maintained. Refer to 4-3-4/1.5.1 of the *Marine Vessel Rules*.

vi) The power distribution system risk assessment report is to be submitted for review, and at a minimum is to address the following aspects:

1) All normal and foreseeable abnormal operating conditions

2) Equipment layout, arrangement, and location

3) Mechanical faults, electrical faults and potential human errors and associated alarms (e.g., earth fault, fire, flooding, cooling/heating failure, and operation exceeding the designed operating parameters)

4) Electrical power system protection philosophy (e.g., loss of cooling power, loss of heating power, loss of control power, loss of power input to main supply, loss of power supply, loss of power on AC and DC bus segment, AC and DC breaker or other protection device failure, earth fault, short-circuit fault)

5) Control component failure (e.g., temperature/pressure sensor failure, generator rectifier/ load inverter failure, AC and DC bus-tie failure, main propulsion thruster drive failure, DP function thruster drive failure, loss of communication)

6) Electrical shock precautions. Consideration to preventing personnel from accessing energized equipment is to be given to the system design and equipment layout.

7) System risk assessment in accordance with Subsection 3/5 of the *Lithium-ion Batteries Requirements*, Fuel Cell risk assessment in accordance with Subsection 2/4 of the *Fuel Cell Power Systems Requirements* and Subsection 3/5 of the *Supercapacitor Requirements*.

17.3 Risk Assessment Techniques

i) The use of risk assessment techniques are to be discussed with ABS prior to performing the risk assessment. The risk assessment is to be carried out in accordance with the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries.*

ii) Several risk assessment techniques may be applied. At the early design stages, a Hazard Identification (HAZID) technique may be conducted to identify potential hazards that could result in consequences to personnel, the environment, and assets. A Hazard and Operability (HAZOP) study may also be conducted to identify and evaluate hazards that may represent risks to personnel or equipment. A Failure Mode and Effects Analysis (FMEA) may also be used to demonstrate that any single failure will not lead to an undesirable event.

19 Emergency Source of Power *(1 April 2024)*

i) Where Internal combustion engine driven emergency generator is being proposed as an emergency source of electric power, the requirements in 4-8-2/5.9.1 and 4-8-2/5.15 of the Marine Vessel Rules are to be complied with.

ii) Where an ESS (e.g., lithium-ion batteries) is being proposed as an emergency source of electric power, it is subject to ABS technical assessment and approval, and all requirements in 4-8-2/5 of the *Marine Vessel Rules* are to be complied with, or 4-3-2/5.3 of the *MOU Rules*, as applicable, are to be complied with.

iii) Where the emergency source of electrical power is Lithium-ion battery, it is to comply with the requirements given in the *ABS Requirements for Use of Lithium-ion Batteries in the Marine and Offshore Industries* regardless of the battery capacity. [see 2/1.18 of that document]

iv) Where the emergency source of electrical power is an accumulator battery, or other ESS, it is to be capable of:

a) Automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power

b) Immediately supplying at least the services specified in 4-8-2/5.11 of the *Marine Vessel Rules* and

c) Carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage.

21 Emergency Switchboard *(1 April 2024)*

The requirements for an emergency switchboard for all-electric power system are to comply with 4-8-2/5.13 of the *Marine Vessel Rules.*

Where the battery system is used as an emergency source of electrical power, the requirements are to be in accordance with 2/1.18 of ABS *Requirements for Lithium-ion Batteries* as applicable.

23 Modeling and Simulation *(1 April 2024)*

Modeling and Simulation may be considered as an alternative approach to some of the physical testing requirements.

A test plan is to be submitted for review and approval showing which items will be validated by physical tests and which ones will be validated by simulation tests.

Model Based Systems Engineering (MBSE), when used in lieu of traditional practices (i.e., Documents Based Systems Engineering), is to meet industry typical requirements for this type of simulation/modeling process.

23.1 General *(1 April 2024)*

i) Modeling and simulation of the hybrid/ all-electric power system offers the capability of providing the information that would normally be obtained from traditional system studies and additional information about operation, configuration, and power quality.

ii) For model verification and validation, acceptable techniques such as these below are acceptable:

- Explore Model Behavior
- Graphical comparison of data
- Confidence intervals
- Hypothesis Tests

23.3 Computer Based System Simulation Testing

When computer-based system simulation testing is conducted as an alternative approach or to supplement the approach to some of the physical testing requirements, the following methods are acceptable. The application of these methods is to be described in the test plan:

i) Model in the Loop (MIL)

Model In the Loop (MIL) testing is to be conducted when, both a numerical model of the multi-physics system and a model of its automation and manual control functions have been verified and validated. In MIL test approach the model and its environment are simulated without any physical hardware components. MIL cannot reveal faults that are caused by the target controller or by the processor architecture.

ii) Software in the Loop (SIL)

During Software In the Loop (SIL) Testing, virtual (emulated) PLCs, with dedicated interfaces to the simulated multi-physics models, are to be considered for deployment of the executable code. Combining the various multi-physics models of connected systems on board with their actual control and automation logic through SIL can offer a higher fidelity virtual testing. This level is essentially a test of the coding system. In the SIL test approach, the model and its virtual (emulated) PLCs are simulated without any physical hardware components. SIL cannot reveal faults that are caused by the target controller or by the processor architecture.

iii) Hardware in the Loop (HIL)

During Hardware in the Loop (HIL) Testing, the control and automations software is fully integrated into the final controller hardware and can only interact with the simulated multi-physics system through the actual I/Os of the controller. The simulated multi-physics system also runs on a real-time computer with I/O simulations to "trick" the controller into believing that it is installed on the actual physical system. In this case, the only difference between the final application and the HIL environment is the fidelity of the simulated multi-physics system model and the test vectors that are being used. HIL level of testing can reveal faults that are caused by the target compiler or by the processor architecture.

iv) The following, is also to be included in the test plan and submitted to ABS for review:

1) Test purpose

2) Test setup including models' parameters

3) Expected results and acceptance criteria

Notes:

1 For software upgrades it is recommended to do a regression testing.

2 Regression testing is re-running functional and non-functional simulation tests to ensure that previously developed and tested software still performs after a change.

23.5 Integration Simulation testing

i) Intra-system integration testing is to be performed between system and sub-system software modules before being integrated on board.

ii) The simulation tests can follow one of the computer-based systems simulation testing methods mentioned in 3/23.3 above as applicable.

iii) Functional and failure testing of the integrated systems identified in 4-9-3/8.3.6 and 4-9-3/8.3.7 of the *Marine Vessel Rules* may be demonstrated by modeling and simulation tests.

25 Station Keeping while charging from Offshore Charging Connection *(1 April 2024)*

Hybrid/All-Electric vessels are to be capable of maintaining their position during charging while connected to an offshore charging station.

Where a vessel utilizes dynamic positioning systems to maintain the vessel's position while charging, they are to comply with DPS-1 notation in accordance with the requirements for the *ABS Guide for Dynamic Positioning Systems*.

27 Safety Interlocks *(1 April 2024)*

Safety interlocks for shore connections are to comply with 6-4-2/21 of the *Marine Vessel Rules*.

29 Fire Safety *(1 April 2024)*

All-electric vessels are to meet the fire safety requirements found in the following ABS documents as applicable:

i) Part 4, Chapter 7 of the *Marine Vessel Rules*

ii) Section 3/3.1 of the *Lithium-ion Batteries Requirements*

iii) Section 4 of the *Fuel Cell Power Systems Requirements*

iv) Section 3/3.3 of the *Supercapacitor Requirements*

31 Safe Return to Designated Safe Area *(1 April 2024)*

i) The vessel is to retain sufficient energy at all times to return to a designated safe area.

ii) The vessel is to retain sufficient energy in one section of the ESS to return to the designated safe area in case of a single failure in the other section.

iii) The vessel is to return to the designated safe area immediately upon detection of abnormal conditions such as thermal runaway and/or loss of one bus section.

iv) The EMS (Energy Management System) is to monitor the SOC (State of Charge) at all times and is to be displayed to the operator.

v) Alarms are to be provided if it is determined that the SOC is approaching the minimum threshold that will not allow the battery system to provide sufficient capacity and power in one section of the ESS to return to the designated safe area.

Commentary:

a Sufficient energy is energy required to navigate to a designated safe area. It can be calculated based on remaining time as defined in 4/3.3 of the *Lithium-ion Batteries Requirements*.

b A designated safe area may be a port, a charging station, or a zone where a vessel in distress can remain clear of other vessels or structures, marine traffic, and heavy weather such as to prevent further damage or deterioration.

c Refer to the *Lithium-ion Batteries Requirements* for abnormal conditions that may trigger the safe return to a designated safe area *BMS (Section 2/5), Gas detection (Section 2/1.12) or Fire and smoke detection (Section 3/3.1).*

d The above details are to be included in the CONOPS. See Section 2/1.3 xxxiii)

End of Commentary

33 Lighting System *(1 April 2024)*

The lighting system requirements for hybrid/all-electric power systems are to comply with 4-8-2/7.13 of the *Marine Vessel Rules* as applicable.

The lighting distribution board requirements are to comply with 4-8-4/11.5 of the *Marine Vessel Rules* as applicable.

35 Vessel Charging System *(1 April 2024)*

35.1 General

This subsection covers requirements for electrical conductors and equipment external to an all-electric vessel that connects the vessel to a supply of electricity and the installation of equipment and devices related to the all-electric vessel's charging

35.3 Equipment construction

35.3.1 Means of coupling

The means of coupling to the electric vessel may be

i) conductive,

ii) inductive, or

iii) wireless power transfer.

For wireless power transfer, mutual inductance between transmitter and receiver coils are to be constant.

Attachment plugs, electric vessel connectors, and electric vessel inlets are to be listed or labeled for the purpose.

35.3.2 Electric Vessel Coupler

An electric vessel coupler where provided is to comply with the following requirements:

i) The coupler is to be provided with a positive means to prevent unintentional disconnection.

ii) If an electric vessel coupler is provided with an earthing pole, it is to be designed in such a way that the earthing pole connection is the first to make and last to break the contact.

35.3.3 Automatic De-energization of Cables

The electric vessel cable-connector is to be provided with an automatic means to de-energize the cable conductors and electric vessel connector upon exposure to strain that can result in either cable rupture or separation of the cable from the electric connector and exposure of live parts.

35.5 Battery Charging while connected to the Load

Where the load is connected to the battery while it is being charged, the maximum battery voltage under any conditions of charging is not to exceed the voltage variation as allowed in 4-8-3/1.9 of the *Marine Vessel Rules* for each connected load.

35.6 Charging Station on the vessel

A charging station provided on the vessel is to be fitted with:

i) AC to DC power conversion equipment as applicable

ii) Power supply equipment

iii) Control schemes and communication

iv) Overcurrent, overvoltage, residual current and ground-fault protection devices as required at the maximum power rating are to be provided

v) Cooling management system to prevent overheating while charging

vi) Digital communication system as per IEC 61851-24 that enables the vessel to control the charging protocols.

SECTION 4
Equipment and Installation

1 Objective *(1 April 2024)*

1.1 Goals and Functional Requirements

The goals and functional requirements in the cross-referenced Rules, other ABS Guides and Requirements Documents are to be met.

3 Electrical Equipment

3.1 General *(1 April 2024)*

In addition to the specific requirements in this Section, the following references are also to be taken into account:

i) Electrical equipment is to be designed, constructed and tested to a national, international or other recognized standard and in accordance with the applicable requirements of Part 4, Chapter 8 of the *Marine Vessel Rules,* or applicable requirements of Part 4, Chapter 3 of the *MOU Rules*.

ii) Computer based systems, where used for control, monitoring and safety systems, are to comply with the requirements of Section 4-9-3 of the *Marine Vessel Rules*.

iii) ABS can consider other industry standards and practices for electrical equipment, on a case-by-case basis, with justifications through novel features and/or comparative analyses to be provided to demonstrate equivalent level of safety to the recognized standards.

iv) For yachts, see Subsection A2/11.

3.3 Transformers and Converters *(1 April 2024)*

Application: Transformers and Converters used in the hybrid/all-electric power systems (e.g., as part of ESS, FC-PS, wind, solar etc.) are to be designed, constructed, and tested as follows:

i) Transformers

Transformers are to be designed, constructed, and tested in accordance with 4-8-2/3.7, 4-8-3/7 and 4-8-5/3.3.3, 4-8-5/3.5. of the *Marine Vessel Rules* as applicable.

ii) Power electronic converters (PEC)

Power electronic converters are typically considered “two port” devices capable of providing unidirectional or bidirectional conversions with independent control of the input/output frequency and input/output voltage ratio. A transformer may be included with the PEC.

Converters are to be designed, constructed, and tested in accordance with 4-8-2/3.7, 4-8-3/5.9, 4-8-3/8 and 4-8-5/3.7.5 of the *Marine Vessel Rules* as applicable.

3.5 Shaft Generators (SG) *(2023)*

i) General

Shaft generators (SG) are used to generate electric power (in PTO mode) and support the ship's service loads if the prime mover has sufficient load margin. The SG is typically driven by slow or medium speed engines (ships' conventional propulsion power system). In some cases, the shaft generator may also be used to boost the propulsion system (used as a motor in PTI mode).

ii) Shaft generators (constant and variable speed drives) are also to comply with 4-8-2/3.5 of *the Marine Vessel Rules* as appropriate.

iii) Operating mode (PTO/PTI), see 3/Table 2 Item 4.

iv) Materials

For material tests of power takeoff generators and power-take-in motors, please see 4-8-5/6.17.1 of the *Marine Vessel Rules*.

v) Gears

When the shaft generator is driven through a reduction gear, the gear box is to be designed, constructed and tested in accordance with Section 4-3-1 of the *Marine Vessel Rules* as applicable.

vi) Shaft generators - Performance Tests

Shaft generators are to be tested at the factory as per 4-8-3/3.17 of the *Marine Vessel Rules*.

vii) Shaft generators installed on board yachts

- Shaft generators are to comply with 4-6-2/3.3 of the *Yacht Rules*.
- See also Appendix 2/Table 1, for shaft generators certification requirements, and Subsection A2/11.

5 Hazardous Area Installation

5.1 Hazardous Area Classification and Requirements

The following requirements as per the references in 4/Table 1, as applicable, are also to be met.

TABLE 1
Hazardous Area Classification *(1 February 2022)*

Applicable System	*Reference*
Battery System Installation	3/3.3 of *Lithium-ion Battery Requirements*
Supercapacitor Systems Installation	3/3.9 of *Supercapacitor Requirements*
Fuel Cell Power Systems Installation	Subsections 5/3, 5/4 of *Fuel Cell Power Systems Requirements*

5.3 Installation in Hazardous Areas *(1 February 2022)*

The following requirements as per the references in 4/Table 2, as applicable, are also to be met.

TABLE 2
Installation in Hazardous Areas

Applicable System	*Reference*
Solar PV Electric Power Generation Systems	5/11.3.2 of this document
Wind Electric Power Generation Systems	6/11.3.2 of this document

SECTION 5

Requirements for Solar PV Electric Power Generation Systems

(1 February 2022)

1 General

1.1 Application *(1 April 2024)*

In addition to the requirements of this document, this Section includes requirements for the design, construction, and testing of hybrid/all-electric power systems utilizing a solar photovoltaic (PV) system for electric power generation on marine and offshore assets, as supplemental source of power. This Section is applicable to non-concentrator photovoltaic panels and does not cover concentrator photovoltaic technologies.

This Section is applicable to PV Solar installations used as a supplemental source of electrical power with a capacity greater than 2 kW.

1.2 Objective *(1 April 2024)*

1.2.1 Goals

The Solar PV Electric Power systems covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 1	provide safe and reliable storage and supply of fuel/energy/power.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
MGMT 5.1	facilitate safe access, ease of inspection, survey, and maintenance of the vessel, machinery and electrical systems.
AUTO 6	independently perform different functions, such that a single failure in one system will not render the others inoperative.
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.

The Goals in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.2.2 Functional Requirements

In order to achieve the above stated Goals, the design, construction, installation, and maintenance of the Solar PV Electric Power systems are to be in accordance with the following Functional Requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Solar PV systems are to be sized to meet the power requirement taking into account environmental, installation and operating conditions.
POW-FR2	Solar PV system is to be designed and constructed to withstand the marine environment and be suitable for the intended service.
POW-FR3	The support structure is to be designed to withstand the maximum expected operational loads under all conditions.
POW-FR4	Provide means to safely store and distribute generated power.
POW-FR5	Solar PV system is to be designed and installed to prevent full or partial shading and hot spots.
POW-FR6	Provide means to ensure that solar PV system and equipment operate within their rated operating temperatures.
POW-FR7	Prevent backflow of current and maintain the reliability of the entire solar power system in the event of a solar panel failure.
Safety Management (MGMT)	
MGMT-FR1	Provide accessibility to all the parts of the equipment for inspection or adjustment or replacement or cleaning.
Automation (Control, Monitoring and Safety systems) (AUTO)	
AUTO-FR1	Solar PV system is to be designed to enable safe operation in the event of failure of the tracking system.
SAFETY OF PERSONNEL (SAFE)	
SAFE-FR1	Provide means of isolation between the power generating PV section and the power conversion equipment to prevent the transfer of electrical faults.
SAFE-FR2	Cable for moving components is to be designed to avoid chafing and undue stress.
SAFE-FR3	Provide marking plates to specify the operational parameters of the solar power system and its components.
SAFE-FR4	Electrical equipment installed in hazardous areas is to be suitable for the environment (gas group and temperature classification) in which they operate.
SAFE-FR5	Protect system components from external damage and maintain safe operation.
SAFE-FR6	Solar panels located in a location where a person can walk over the PV array are to have adequate strength to withstand the impact of being stepped on and suitable arrangements are to be provided to prevent injury to crew.
SAFE-FR7	Solar power system is to be designed so that they do not interfere with safe navigation.
SAFE-FR8	Minimize or prevent potential hazards from the reflection of Solar PV array.

The Functional Requirements in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.2.3 Compliance

Solar PV Electric Power systems are considered to comply with the Goals and Functional Requirements within the scope of Classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

3 Plans and Data to be Submitted *(1 April 2024)*

In addition to those in 2/1.3 and 2/1.5, the following plans, data, and specifications covering the solar photovoltaic (PV) system for electric power generation are to be submitted for review as applicable:

The following symbols are used in this section for the type of review of the documents:

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review

OB: Documentation which needs to be kept onboard

i) Documentation showing sizing and optimization calculations of the hybrid/all-electric power system **(R)**

ii) Arrangement of solar PV system and installation location(s) **(R)**

iii) Structural load analysis report and loads used for structural design of support structure, if applicable **(R)**

iv) Detail drawings of the foundation and support structure on which the solar PV system is installed **(R)**

v) Calculations for the foundation and hull interface structure **(R)**

vi) Vessel stability review **(R)**

vii) Anchoring and mooring equipment specifications, where required **(I)**

viii) Electrical system integration plan of solar PV system with ESS and onboard power supply **(R)**

ix) Procedure for temporary removal of solar PV array(s), if applicable. See 5/11.3.3 **(R)**

x) Solar PV system documentation in accordance with Clause 4 of IEC 62446-1, which includes the following: **(R)**

- System data, including system designer and installer information
- Wiring diagram annotated with PV array design, PV string information, PV array electrical details, AC system information, and earthing and overvoltage protection information
- String layout
- Datasheets for PV modules, inverters, and other system components
- Mechanical design information
- Emergency systems documentation
- Operation and maintenance information
- Test results and commissioning data, certificates, as appropriate, etc.

5 Certification

5.1 General

Solar PV system components are to be tested and certified in accordance with the following 5/Table 1. Test reports are to be submitted to ABS and are to be available to the attending Surveyor.

TABLE 1
Components Testing Requirements

Component	*Reference*	*ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)*
Solar PV Modules	IEC 61215 Series, IEC 61730 Series, IEC 61701 [(1)]	2
Bypass Diodes and Blocking Diodes (if applicable)	IEC 61701 [(1)]	2
Power Conversion Equipment (PCE)	IEC 62109 Series [(2)]	2
Junction Boxes	IEC 62790	2
Tracker (if applicable)	IEC 62817	2
Solar PV System	IEC 62446 Series	2
All components[(5)]	IEC 60068-2-52 Test Kb [(3)], IEC 60068-2-6 Test Fc [(4)]	2

Notes:

1 Solar PV modules and bypass or blocking diodes (if applicable) are to be tested and certified in accordance with IEC 61701. The selected test methods are to correspond to the product use in a marine or offshore environment.

2 IEC 62109-1 provides general testing requirements for power conversion equipment for use in solar PV systems. IEC 62109-2 and IEC 62109-3 are to be referenced for alternative or additional testing requirements applicable to the PCE technology used in the solar PV system.

3 Solar PV system components other than solar PV modules and bypass or blocking diodes (e.g., power conversion equipment, junction boxes, etc.) are to be tested in accordance with IEC 60068-2-52 Test Kb (Salt Mist Environmental Test). The selected test methods are to correspond to the product use in a marine or offshore environment.

4 All solar PV system components are to be tested in accordance with IEC 60068-2-6 Test Fc (Vibration Environmental Testing). The selected test severity is to correspond to the product use in a marine or offshore environment.

5 Solar PV system components other than solar PV modules and bypass or blocking diodes (e.g., power conversion equipment, junction boxes, etc.) are to have ingress protection no less than IP 56 according to 4-8-3/Table 2 of the *Marine Vessel Rules*.

7 Onboard Documentation (OB, R) *(1 April 2024)*

i) Nondestructive testing (NDT) that includes in service inspection plans for review at each annual/periodic survey and records for critical steel structure welds on support structures constructed of steel, if applicable

ii) Procedure for temporary removal of solar PV array(s), if applicable. See 5/11.3.3

iii) Solar PV system documentation in accordance with Clause 4 of IEC 62446-1 (see 5/3.*x*) and Clause 4 of IEC 62446-2, which includes the following:

- Performance benchmarking
- Documentation of records, including test data and maintenance procedures

9 System Design

9.1 General

In addition to the requirements in Section 3, the solar PV system is to comply with the requirements provided in this Subsection, as applicable.

9.3 System Configuration

9.3.1 System Sizing and Arrangement

The solar PV system is to be designed in accordance with the requirements and considerations in IEC 62548.

System sizing calculations are to consider the aggregate area of the solar PV array(s), the efficiencies and degradation rates of the PV modules and system components, and historical or estimated irradiance and weather data representative of the region(s) and season(s) in which the vessel operates.

Note:

In general, the solar PV system design should optimize the orientation(s) and curvature (if applicable, e.g., for flexible panels) of the PV modules. The solar PV system location(s) and arrangement should eliminate or minimize the likelihood of full or partial shading on the PV array(s) and the potential hazards from solar glint and glare from reflections from the PV array(s).

For systems using a solar tracker to position the PV modules relative to the path of the sun, the system sizing calculations are to also consider the expected increase in power production (relative to a fixed installation) and the power consumption by the tracker and related control system(s). The installation location is to have sufficient area to allow movements by the tracker.

For systems using a solar tracker, the tracker system is to be designed and tested in accordance with the requirements of IEC 62817 applicable to standard PV module trackers.

9.3.2 Materials and Design

The materials used in the construction of the solar PV system and support structure are to be designed and approved for use in a marine environment and suitable for the intended service conditions.

9.3.3 Support Structure

Foundations and vessel interface structure are to be of ample strength and stiffness to withstand the maximum expected operational loads. The load of Solar PV system when installed on the deck is not to exceed the rated deck capacity. Where the deck load exceeds the rated deck capacity the vessel scantlings are to be evaluated using Section 3-2-20 of the *Marine Vessel Rules*.

The support structure or mounting arrangement (e.g., adhesive, bolts, ties, or other mounting) for the PV modules is to be designed in accordance with Subclause 5.2 of IEC 62548 and is to account for the wind effect, operating modes, and load considerations.

For systems with solar PV arrays that are designed to be temporarily removed, the support structure or mounting arrangement is to allow for the safe disconnection, storage, and reconnection of the PV array(s) by the crew. See 5/11.3.3 of this document.

9.5 Power Distribution System

9.5.1 General

In addition to the requirements of Subsection 3/5, the solar PV system is to comply with the requirements provided in this subsection, as applicable.

For Direct Current (DC) power distribution systems, see the ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications* for supplemental requirements.

9.5.2 ESS Integration

Since the power production of solar PV panels depends on the ambient environment and is available at the system's rated output under limited conditions, solar PV systems are to be integrated with an energy storage system to stabilize, store, and distribute the generated power to the vessel's electric power system.

ESSs charged by intermittent power generation sources (i.e., solar PV panels or wind turbines) are to be limited to feeding non-essential service loads unless the risk assessment can demonstrate vessel safety and continuity of power supply to essential service loads during ambient environment conditions in which the solar PV system produces less than the system's rated output or does not produce power.

ESSs are to be designed and constructed in accordance with A1/1.1 and A1/1.3, 4-8-3/5.9 and 4-8-4/5 of the *Marine Vessel Rules*, as applicable.

Solar PV arrays used for battery charging are to comply with Subclauses 5.1.7 and 6.5.6 of IEC 62548.

9.7 Control and Instrumentation *(1 April 2024)*

In addition to the requirements in Subsection 3/7, the solar PV system is to comply with the requirements provided in this Subsection, as applicable.

The control, monitoring, alarm, and safety systems of the solar PV array(s) and solar tracker (if applicable) are to be in accordance with Sections 4-9-2 and 4-9-3 of the *Marine Vessel Rules*, as applicable.

Note:

The control system of the solar PV array(s) may use a maximum power point tracking (MPPT) control strategy or other suitable control strategy considered not less effective.

For systems using a solar tracker, the control system of the tracker is to be designed to counteract the different operational and environmental conditions to which the vessel is subjected. Failure of the tracker system is not to cause unsafe operation of the solar PV system.

To isolate the PV section from a PCE, a switch-disconnector device is to be provided.

9.9 Electrical Protection System

9.9.1 General

In addition to the requirements in Subsection 3/9, the solar PV system is to comply with the requirements provided in this Subsection as applicable.

Protection requirements specific to solar PV arrays are specified in Clause 6 of IEC 62548 as follows:

- 6.1.2 – Separation of PV array from main AC power output circuits
- 6.2 – Protection against electric shock
- 6.3 – Protection against thermal effects
- 6.4 – Protection against the effects of insulation faults
- 6.5 – Protection against overcurrent

- 6.6 – Protection against effects of lightning and overvoltage

9.9.2 Shutdown Procedures

The operation and maintenance manuals of the solar PV system are to include the procedures for normal shutdown and emergency shutdown, including electrical isolation of system components. Parts of the Subclauses 13.2 and 13.3 of IEC 62446-2 that may be applicable to solar PV systems regarding safety and isolation procedures are to be complied with.

9.9.3 Shading and Hot Spot Prevention

The design and installation of the solar PV system is to prevent full or partial shading and hot spots as far as practicable. Solar PV arrays are to be regularly cleaned of salt or debris accumulations, which effectively cause shading and subsequent hot spots, in accordance with the system operation and maintenance procedures.

For systems using bypass diodes or blocking diodes, see 5/11.1.6.

9.11 Vessel Stability

A vessel stability review considering the location(s) and added weight of the solar PV system is to be conducted in accordance with Section 3-3-1 of the *Marine Vessel Rules*, as applicable, and submitted to ABS for review.

9.13 Anchoring and Mooring Equipment

The additional side projected area and weight introduced by the installation of the solar PV system is to be considered during the Equipment Numeral (EN) determination for anchoring and mooring equipment in accordance with Subsection 3/6 of the ABS *Requirements for Wind Assisted Propulsion System Installation*.

11 Electrical Equipment and Installation

11.1 Electrical Equipment

11.1.1 General

In addition to the requirements of Section 4, the solar PV system is to comply with the requirements provided in this Subsection and Clause 7 of IEC 62548, as applicable.

11.1.2 Temperature Rating

According to Subclause 7.3.7.2 of IEC 62548, PV modules frequently operate at temperatures of the order of 40°C above ambient temperature. The solar PV system components in contact with or near the PV modules are to be rated accordingly. Insulation materials are to be selected in accordance with 4-8-3/1.15 of the *Marine Vessel Rules*.

The solar PV panels are to be rated for open deck ambient temperatures in accordance with 4-8-3/1.17 of the *Marine Vessel Rules*.

The PV array(s) and electrical equipment are to have adequate ventilation and methods for cooling and heating (if applicable) to protect the system from extreme temperatures and keep the system within the rated operating temperature range of the components, in accordance with Subclause 5.1.9 of IEC 62548.

The solar PV array maximum voltage and voltage correction factor is to be determined using the lowest expected operating temperature in accordance with Subclause 7.2 of IEC 62548.

11.1.3 Cables

Cables for the solar PV system are to be designed and installed in accordance with 4-8-3/9 and 4-8-4/21 of the *Marine Vessel Rules* and Subclause 7.3.7 of IEC 62548.

For a system with moving components (e.g., solar tracker), the cable design is to consider the system's range of motion and mechanical stresses induced by cable movement.

11.1.4 Power Conversion Equipment (PCE)

Refer to the following, as applicable:

i) 4/1.3

ii) Subsection 3/11 of the ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications*

iii) IEC 62109 Publication Series

Power conversion equipment is also to be tested in accordance with Section 8/Table 1.

11.1.5 Junction Boxes

Junction boxes for solar PV modules are to comply with 4-8-3/9.21 and 4-8-4/21.25 of the *Marine Vessel Rules* and with IEC Publication 62790. Junction boxes are to be tested in accordance with 5/Table 1.

11.1.6 Bypass Diodes and Blocking Diodes

The solar PV system may use bypass diodes for protection from reverse voltage bias and hot spots and/or use blocking diodes for protection from reverse currents.

Bypass diodes, where used, are to comply with Subclauses 7.3.2.1 and 7.3.11 of IEC 62548. Blocking diodes, where used, are to comply with Subclause 7.3.12 of IEC 62548. Bypass diodes and blocking diodes are to be tested in accordance with 5/Table 1.

11.1.7 Warning Labels and Markings

All PV Solar electrical equipment is to be clearly labeled and marked in accordance with clause 10 of the IEC 62548 standard as appropriate.

11.3 Installation

11.3.1 General

In addition to the requirements of Section 4-8-4 of the *Marine Vessel Rules*, the solar PV system is to comply with the requirements provided in this Subsection, as applicable.

11.3.2 Installation in Hazardous Areas

The installation of PV Solar equipment is to avoid locations of hazardous areas.

However, where the location for the installation of the solar PV system is within a hazardous area, the equipment selection is to comply with 4-8-4/27 of the *Marine Vessel Rules* or Section 4-3-6 of the *MOU Rules* as applicable.

11.3.3 Physical Protection of Installation

The solar PV system is to be installed in a location where the PV array(s) will be protected from physical impacts or damage and will not adversely affect the normal operation of the vessel.

The solar PV system may be designed to allow temporary removal of the PV array(s) for protection during conditions in which physical damage to the array(s) is likely to occur (e.g., during extreme weather events or during cargo handling operations).

For systems with PV arrays that are designed to be temporarily removed, a documented procedure is to be submitted to ABS for review and retained on board detailing the safe electrical and physical disconnection, storage, and electrical and physical reconnection of the PV array(s) by the crew. The test plans submitted to ABS for approval are to include the demonstration of this procedure to the satisfaction of the attending Surveyor.

11.3.4 Access and Crew Protection

Accessibility to electrical equipment for inspection or adjustment is to be in accordance with 4-8-3/1.13 of the *Marine Vessel Rules* and Subclause 7.3.3.2 of IEC 62548.

For solar PV systems located where persons may walk on the PV array(s), the PV panels are to be designed to withstand the impact of being walked on and are to have measures for preventing slips and falls (e.g., a non-slip coating on the surface of the PV panels, temporary installed handrails). Barriers or warning labels and markings are to be in place such that high voltage installations and PV arrays using a solar tracker are not to be walked on.

11.3.5 Navigation Safety

The solar PV system is to be designed to eliminate or minimize the potential hazards from solar glint and glare from reflections from the PV array(s).

The installation of the solar PV system is to comply with the visibility and navigation requirements of Section 3-6-1 of the *Marine Vessel Rules* and Subsection 3/4 of the ABS *Requirements for Wind Assisted Propulsion System Installation* as applicable.

SECTION 6

Requirements for Wind Electric Power Generation Systems *(1 February 2022)*

1 General

1.1 Application *(1 April 2024)*

In addition to the requirements of this document, this Section includes requirements for provisions that apply to the design, construction, and testing of hybrid/all-electric power systems utilizing wind turbine generators for electric power generation on marine and offshore assets, as supplemental sources of power. This Section is applicable to small wind turbines as defined by IEC 61400-2, defined below.

This Section is applicable to wind turbine installations used as a supplemental source of electrical power with a capacity greater than 2 kW.

1.2 Objective *(1 April 2024)*

1.2.1 Goals

The Wind Electric Power Generation Systems covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 1	provide safe and reliable storage and supply of fuel/energy/power.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
MGMT 5.1	facilitate safe access, ease of inspection, survey, and maintenance of the vessel, machinery and electrical systems.
AUTO 6	independently perform different functions, such that a single failure in one system will not render the others inoperative.
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.

The Goals in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.2.2 Functional Requirements

In order to achieve the above stated Goals, the design, construction, installation, and maintenance of the Wind Electric Power Generation Systems are to be in accordance with the following Functional RequirementsIn order to achieve the above stated Goals, the design, construction, installation, and maintenance of the Solar PV Electric Power systems are to be in accordance with the following Functional Requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Wind turbine systems are to be sized to meet the power requirement taking into account environmental, installation and operating conditions.
POW-FR2	Wind turbin is to be located to maximize airflow and to operate the turbine without disturbances.
POW-FR3	Wind turbine generator system is to be designed and constructed to withstand the marine environment and be suitable for the intended service.
POW-FR4	Provide means to safely store and distribute generated power.
POW-FR5	Solar PV system is to be designed and installed to prevent full or partial shading and hot spots.
POW-FR6	Provide means to ensure that wind turbine generator system electrical equipment operates within their rated operating temperatures.
Safety Management (MGMT)	
MGMT-FR1	Provide accessibility to all the parts of the equipment for inspection or adjustment or replacement or maintenance.
Automation (Control, Monitoring and Safety systems) (AUTO)	
AUTO-FR1	Wind turbine generator system is to be designed to enable safe operation in the event of failure of any control systems.
AUTO-FR2	Provide means to control the overspeed of wind turbines to prevent catastrophic failures that may have unexpected consequences.
SAFETY OF PERSONNEL (SAFE)	
SAFE-FR1	Provide means to protect the wind turbine generator systems from lightning.
SAFE-FR2	Cable for moving components is to be designed to avoid chafing and undue stress.
SAFE-FR3	Electrical equipment installed in hazardous areas is to be suitable for the environment (gas group and temperature classification) in which they operate.
SAFE-FR4	Protect system components from external damage and maintain safe operation.
SAFE-FR5	Provide suitable arrangements to protect crews from potential hazards caused by moving parts of the wind turbine generator system.
SAFE-FR6	Wind turbine generator system is to be designed so that they do not interfere with safe navigation.

The Functional Requirements in the cross-referenced Rules, other ABS Guides and Requirements Documents are also to be met.

1.2.3 Compliance

The Wind Electric Power Generation systems are considered to comply with the Goals and Functional Requirements within the scope of Classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Plans and Data to be Submitted *(1 April 2024)*

In addition to Section 2/1.3 and 2/1.5, the following plans, data, and specifications covering the wind electric power generation system are to be submitted for review as applicable:

The following symbols are used in this section for the type of review of the documents:

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review

OB: Documentation which needs to be kept onboard

i) Documentation showing sizing and optimization calculations of the hybrid/all-electric power system **(R)**

ii) Arrangement of wind turbine generator system and installation location(s) **(R)**

iii) Structural load analysis report and loads used for structural design of support structure **(R)**

iv) Detail drawings of the foundation and support structure on which the wind turbine generator is installed **(R)**

v) Calculations for the foundation and hull interface structure **(R)**

vi) Vessel stability calculation including the effect of wind turbine **(R)**

vii) Anchoring and mooring equipment specifications (Compliance with Ⓔ requirements is a condition of classification for vessels, for which the equipment number (EN) calculated in accordance with 3-5-1/3.1 of the *Marine Vessel Rules* is equal to or greater than 205) **(I)**

viii) Electrical system integration plan of wind turbine generator system with ESS and onboard power supply **(R)**

ix) Manufacturer's design documentation for design class "S" wind turbine. See 6/9.17 **(R)**

x) Procedure for lowering wind turbines on tilt-up towers, if applicable **(R)**

xi) Procedure for temporary removal of wind turbine(s) and/or wind turbine blades, if applicable. See 6/11.3.3 **(R)**

xii) Wind turbine generator system documentation in accordance with Clause 11 of IEC 61400-2, which includes the following:

xiii)
- Wind turbine technical specifications, including vibration and noise specifications for all operating conditions
- Installation information, including drawings, installation procedures, a wiring diagram, and support structure information
- Operation manual, including manual and emergency shutdown information
- Maintenance and routine inspection information, including safety procedures and list of components to inspect and service
- Consumer label

xiv) Test plans **(R)**

5 Certification

5.1 General

The wind turbine generator system is to be tested and certified in accordance with 5/Table 1 below. Test reports are to be submitted to ABS and are to be available to the attending Surveyor.

TABLE 1
Wind Turbine Generator System Testing Requirements[3]

Test	*Reference*
Tests to verify design data	IEC 61400-2
Mechanical loads test	IEC 61400-2
Duration test	IEC 61400-2
Mechanical component tests	IEC 61400-2
Safety and function test	IEC 61400-2
Environmental test	IEC 61400-2
Electrical test	IEC 61400-2
Power performance test	IEC 61400-12-1 Annex H
Acoustic noise test	IEC 61400-11 Annex F
Salt Mist Test [1]	IEC 60068-2-52 Test Kb
Vibration test [2]	IEC 60068-2-6 Test Fc

Notes:

1 Wind turbine generator system components or equipment are to be tested in accordance with IEC 60068-2-52, Test Kb. The selected test methods are to correspond to product use in a marine or offshore environment. See item 10 "Salt Mist" of 4-9-9/15.7 Table 1 of the *Marine Vessel Rules*.

2 Wind turbine generator system components or equipment are to be tested in accordance with IEC 60068-2-6, Test Fc. The selected test severity are to correspond to product use in a marine or offshore environment. See item 5 "Vibration" of 4-9-9/15.7 Table 1 of the *Marine Vessel Rules*.

3 The equipment/system can be accepted based on the manufacturers' documentation and quality as required in the IEC standards (including Standard tests reports, Certification, etc.).

7 Onboard Documentation (OB, R) *(1 April 2024)*

i) Nondestructive testing (NDT) that includes in service inspection plan for annual/periodic surveys and records for critical steel structure welds on support structures constructed of steel, if applicable

ii) Procedure for lowering and raising wind turbines on tilt-up towers, if applicable

iii) Procedure for temporary removal of wind turbine(s) and/or wind turbine blades, if applicable. See 6/11.3.3

iv) Wind turbine generator system documentation in accordance with Clause 11 of IEC 61400-2. See 6/3.*xii)* of this document

9 System Design

9.1 General

In addition to the requirements of Section 3, the wind turbine generator system is to comply with the requirements provided in this Section, as applicable.

9.3 System Configuration

9.3.1 System Sizing and Arrangement

The wind turbine is to be designed in accordance with the requirements and considerations in Clause 7 of IEC 61400-2 and is to be designed for the dynamic environment of a vessel, accounting for the wind effect, operating modes, and load considerations in Subsection 3/2 of the ABS *Requirements for Wind Assisted Propulsion System Installation*.

System sizing calculations are to consider the aggregate output of the wind turbine(s) in all operating wind conditions, the efficiencies and degradation rates of the wind turbine(s) and system components, and historical or estimated wind and weather data representative of the region(s) and season(s) in which the vessel operates.

The location(s) of the wind turbine generator system is to eliminate or minimize disturbances in the airflow to the wind turbine(s) from obstructions on board (including other wind turbines) and have sufficient area for furling, pitching, and/or yawing, if applicable.

9.3.2 Materials and Design

The materials used in the construction of the wind turbine generator system are to be designed and approved for use in a marine environment and suitable for the intended service conditions in accordance with 4-8-3/1.7 of the *Marine Vessel Rules*.

9.3.3 Support Structure

The support structure of the wind turbine generator system including system foundation structure and vessel structure supporting the system foundation are to be designed in accordance with Subsection 3/2 of the ABS *Requirements for Wind Assisted Propulsion System Installation*.

Support structures constructed of steel are to undergo nondestructive testing on the critical steel structure welds in accordance with 4/2.2 of the ABS *Requirements for Wind Assisted Propulsion System Installation*.

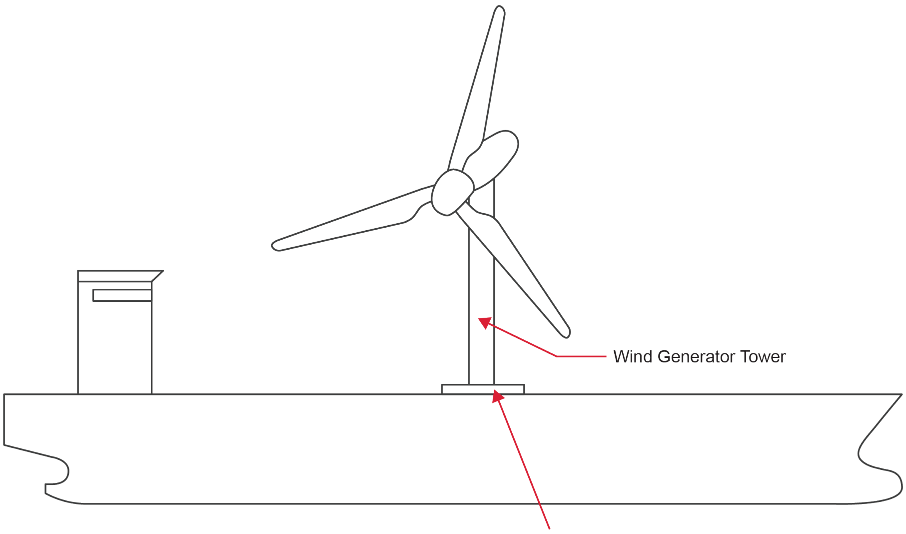
The wind generator tower is outside the scope of class. Refer to Section 6/Figure 1.

Notes:

1 The support structure for wind turbines of up to 40 m^2 rotor swept area that may use a tilt-up tower to lower the wind turbine for protection and/or accessibility for inspection and maintenance shall be designed in accordance with Subclause 8.4 of IEC 61400-2.

2 For systems having wind turbines that are designed to be temporarily removed or lowered, see 6/11.3.3 of this document.

FIGURE 1
Typical Wind Turbine Generator Installation



9.3.4 Structure Simulation Modeling

Subclause 7.5 of IEC 61400-2 may be used for design and testing of the wind turbine generator system, provided that all plans and data requested in Subsection 6/3 are submitted.

Where it is not practicable to test the actual wind turbine generator system in the intended operating conditions, modeling and simulation is to be used to validate the design and analyze the system performance. The modeling and simulation are to account for the wind effect, windage obstructions on board, operating modes, and load considerations the wind turbine generator system may be subject to.

9.5 Power Distribution System

9.5.1 General

In addition to the requirements of Subsection 3/5, the wind turbine generator system is to comply with the requirements provided in this Subsection, as applicable.

For Direct Current (DC) power distribution systems, see the ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications* for supplemental requirements.

9.5.2 ESS Integration

Since the power production of wind turbines depends on the ambient environment and is available at the system's rated output under limited conditions, wind turbine generator systems may be integrated with an energy storage system to stabilize, store, and distribute the generated power to the vessel's electric power system.

ESSs charged by intermittent power generation sources (i.e., solar PV panels or wind turbines) are to be limited to feeding non-essential service loads unless the risk assessment can demonstrate vessel safety and continuity of power supply to essential service loads during ambient environment conditions in which the wind turbine generator system produces less than the system's rated output or does not produce power.

ESSs are to be designed and constructed in accordance with A1/1.1 and A1/1.3, 4-8-3/5.9 and 4-8-4/5 of the *Marine Vessel Rules*, as applicable.

Wind turbines used for battery charging are to comply with Subclauses 6.6.3.1 and 9.7.2 of IEC 61400-2.

9.7 Control and Instrumentation

The control, monitoring, alarm, and safety systems of the wind turbine generator system are to be in accordance with Clause 8 of IEC 61400-1 and Clause 8 of IEC 61400-2.

See also Subsection 3/7, as applicable.

For wind turbines with yaw, pitch, and/or brake mechanisms, the mechanical systems are to be in accordance with Clause 9 of IEC 61400-1 as applicable. Active, passive or manual wind turbine control systems for yawing, pitching, braking, and/or other mechanisms for adjusting power or rotational speed are to be designed to counteract the different operational and environmental conditions to which the vessel is subjected. Yaw misalignment or failure of any such control system is not to cause unsafe operation of the wind turbine generator system.

9.9 Electrical Protection System

9.9.1 General

In addition to the requirements of Subsection 3/9, the wind turbine generator system is to comply with the requirements provided in Clause 9 of IEC 61400-2.

9.9.2 Shutdown Procedures

The protection and shutdown systems for the wind turbine(s) are to be in accordance with Clause 8 IEC 61400-2. The operation and maintenance manuals of the wind turbine generator system are to include the procedures for normal shutdown and emergency shutdown, including a manually operated emergency shutdown method in case of control system failure and procedures for electrical isolation of system components. The shutdown systems of the wind turbine(s) are to include a means of overspeed control.

9.9.3 Lightning Protection *(1 April 2024)*

Wind turbine generator systems are to be protected from lightning in accordance with Subclause 9.5 of IEC 61400-2.

9.11 Vessel Stability

A vessel stability review considering the location(s), added weight, and forces (e.g., thrust, drag) of the wind turbine generator system is to be conducted in accordance with Subsection 3/3 of the ABS *Requirements for Wind Assisted Propulsion System Installation* and Section 3-3-1 of the *Marine Vessel Rules*, as applicable, and submitted to ABS for review.

9.13 Anchoring and Mooring Equipment

The additional side projected area and weight introduced by the installation of the wind turbine generator system is to be considered during the equipment number (EN) determination for anchoring and mooring equipment in accordance with Subsection 3/6 of the ABS *Requirements for Wind Assisted Propulsion System Installation*.

9.15 Vibration and Noise

9.15.1 General

Vibration and noise produced by the wind turbine generator system are to be specified by the wind turbine manufacturer for all operating conditions of the wind turbine.

9.15.2 Vibration and Noise Levels

Vibration and noise levels are to comply with the applicable sections of:

i) The whole-body vibration criteria based on ISO 21984:2018

ii) For the noise criteria, refer to Subsection 4/5 of the ABS *Guide for Crew Habitability on Ships*

9.15.3 Dynamic Behavior

The vibration from the wind turbine is to be assessed in accordance with Subclause 13.4.3 of IEC 61400-2.

9.17 Wind Turbine Class

9.17.1 General

The wind turbine is to be of small wind turbine (SWT) class "S" in accordance with Subclause 6.2 of IEC 61400-2 where special or severe design conditions are necessary to consider.

The wind turbine manufacturer is to provide design documentation as specified in Annex B of IEC 61400-2. The design documentation is to also specify how the wind turbine is designed for operation outside of standard external conditions, in accordance with Annex J of IEC 61400-2, including operations in low temperature, ice, high temperature, and marine applications.

9.17.2 Structural Considerations

The wind turbine support structure or mounting arrangement are to be designed for marine and offshore operating conditions in accordance with Subsection 3/2 of the ABS *Requirements for Wind Assisted Propulsion System Installation* and Clause 6 of IEC 61400-2.

11 Electrical Equipment and Installation

11.1 Electrical Equipment

11.1.1 General

In addition to the requirements of Section 4, the wind turbine generator system is to comply with the requirements provided in this Section, as applicable.

11.1.2 Temperature Rating

The wind turbine generator system electrical equipment, including the wind turbine(s), is to be rated for open deck ambient temperatures in accordance with 4-8-3/1.17 of the *Marine Vessel Rules*. Insulation materials are to be selected in accordance with 4-8-3/1.15 of the *Marine Vessel Rules*.

The wind turbine(s) and electrical equipment are to have adequate ventilation and methods for cooling and heating (if applicable) to protect and keep the system within the rated operating temperature range of the components, in accordance with Subclause 10.3 of IEC 61400-1. Wind turbines operating in cold climate weather conditions are to comply with Clause 14 of IEC 61400-1, as applicable.

11.1.3 Cables

As applicable, cables for the wind turbine generator system are to be designed and installed in accordance with 4-8-3/9 and 4-8-4/21 of the *Marine Vessel Rules* and Subclause 9.6 of IEC 61400-2.

For a system with moving components (e.g., yawing mechanism), the system's range of motion and mechanical stresses induced in the cables by the movement or twisting is to be taken into account in the system design.

11.1.4 Power Conversion Equipment (PCE)

Refer to Subsection 3/11 of the ABS *Requirements for Direct Current (DC) Power Distribution Systems for Marine and Offshore Applications*, as applicable:

See also Subclause 9.7.3.3 of IEC 61400-2. PCE includes protection from harmonic distortion and other electronic interferences. Power conversion equipment is to undergo salt mist and vibration tests in accordance with Section 6/Table 1 of this document.

11.3 Installation

11.3.1 General

In addition to the requirements of Section 4-8-4 of the *Marine Vessel Rules*, the wind turbine generator system is to comply with the requirements provided in this Subsection, as applicable.

11.3.2 Installations in Hazardous Areas

The Installation of wind turbine generator system is to avoid locations of hazardous areas.

In cases where the above cannot be met, the equipment selection is to fully comply with 4-8-4/27 of the *Marine Vessel Rules* or Section 4-3-6 of the *MOU Rules* as applicable.

11.3.3 Physical Protection of Installation

The wind turbine generator system is to be installed in a location where the wind turbine(s) will be protected from physical impacts or damage and will not adversely affect the normal operation of the vessel.

The wind turbine generator system may be designed to allow temporary removal of the wind turbine(s) or the wind turbine blades for protection during conditions in which physical damage to the wind turbine(s) or wind turbine blades is likely to occur (e.g., during extreme weather events or during cargo handling operations).

The system may also use a tilt-up tower to lower wind turbines of 40 m^2 rotor swept area or less for protection. The wind turbine manufacturer is to provide a procedure for lowering wind turbines on tilt-up towers.

For systems having wind turbines or wind turbine blades that are designed to be temporarily removed, a documented procedure is to be submitted to ABS for review and retained on board detailing the safe electrical and physical disconnection, storage, and electrical and physical reconnection of the wind turbine(s) and/or wind turbine blades by the crew. The test plans submitted to ABS for approval are to include the demonstration of this procedure to the satisfaction of the attending Surveyor.

11.3.4 Access and Crew Protection

Accessibility to electrical equipment for inspection or adjustment is to be in accordance with 4-8-3/1.13 of the *Marine Vessel Rules*. Wind turbines of 40 m^2 rotor swept area or less may use a tilt-up tower to lower the wind turbine for inspection and maintenance, in accordance with Subclause 8.4 of IEC 61400-2.

Measures are to exist to protect the crew from the potential hazards from the moving and rotating parts of the wind turbine generator system by providing safe passage. If no measure exists, the installation is to be in accordance with 3-2-17/3 of the *Marine Vessel Rules*.

11.3.5 Navigation Safety

The installation of the wind turbine generator system is to comply with the visibility and navigation requirements of Section 3-6-1 of the *Marine Vessel Rules.* Also, see Subsection 3/4 of the ABS *Requirements for Wind Assisted Propulsion System Installation* for additional guidance.

SECTION 7
Tests and Trials

1 Surveys During Construction

1.1 General *(1 April 2024)*

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of hybrid/all-electric power systems on board. For surveys at the manufacturer's facility, the scope of the survey will be confined to those items that are supplied by the manufacturer.

1.3 Surveys at Manufacturer's Facility *(1 April 2024)*

See Section 2/Table 1 and Section 2/Table 2 of this document for certification requirements of hybrid/all-electric power systems. Survey requirements for equipment components at the manufacturer's facility are summarized in the relevant sections of the applicable Rules/Guides.

i) The manufacture, testing, inspection, and documentation of the hybrid/all-electric power systems is to be in accordance with applicable ABS Rules, recognized standards and the requirements given in this Section.

ii) At the option of the manufacturer, each machine design or type may be enrolled in the ABS Type Approval Program in accordance with the provisions of 1-1-A3/5.1 of the ABS *Rules for Conditions of Classification (Part 1)*. The details of the ABS approval may be posted on the ABS website, http://www.eagle.org/typeapproval.

1.5 Tests for Control, Monitoring and Safety System *(1 April 2024)*

i) Equipment in association with control, monitoring and safety systems of the hybrid/all-electric power generating plant for vessels and offshore installations are to be performance tested in accordance with 4-9-9/13 of the *Marine Vessel Rules*, as applicable.

ii) Indications of parameters necessary for the safe and effective operation of the control, monitoring and safety system are to be tested and verified according to 3/7.7, as applicable.

iii) Simulation testing for verification of the systems/equipment integration may be performed as per 3/19.7.

1.7 Initial Survey *(1 April 2024)*

1.7.1 Onboard Testing *(1 April 2024)*

i) General

- Onboard testing is to verify that functionality has been achieved with all systems in operation.

- The hybrid/all-electric power system installations, as appropriate, are to be examined and tested to the satisfaction of the attending Surveyor in accordance with the approved test plans.
- Section 7/Table 1 shows references to the applicable requirements for the electrical equipment installed on board the vessel, as given in Section 4-8-4 of the *Marine Vessel Rules*, and in the applicable ABS Guides.
- For yachts, please see Appendix 2/13.1.3.

TABLE 1
Electrical Equipment Installation and Test[1] *(1 February 2022)*

Item	*References*
Degree of Enclosure	4-8-4/1.3 of *Marine Vessel Rules*
Inclination	4-8-4/1.7 of *Marine Vessel Rules*
Generators and Motors	4-8-4/3 of *Marine Vessel Rules*
Accumulator Batteries	4-8-4/5 of *Marine Vessel Rules*
Switchboard and Distribution Boards	4-8-4/7 of *Marine Vessel Rules*
Motor Controllers and Motor Control Centers	4-8-4/9 of *Marine Vessel Rules*
Cable	4-8-4/21 of *Marine Vessel Rules*
Equipment Earthing	4-8-4/23 of *Marine Vessel Rules*
System Earthing	4-8-4/25 of *Marine Vessel Rules*
Electrical Equipment in Hazardous Areas	4-8-4/27 of *Marine Vessel Rules*
Shipboard Tests	4-8-4/29 of *Marine Vessel Rules*
Battery System Testing Requirements	Section 3 of *Lithium-ion Batteries Requirements*
Transformers	4-8-3/7.3.5 of *Marine Vessel Rules*
Converters	4-8-3/8.7 of *Marine Vessel Rules*
Supercapacitor System Testing Requirements	Section 3 of *Supercapacitor Requirements*
Fuel Cell Power System Testing Requirements	Sections 6, 7 and 8 of *Fuel Cell Power Systems Requirements*
Solar PV Electric Power Generation System Testing Requirements	Section 5 of this document
Wind Electric Power Generation System Testing Requirements	Section 6 of this document

Note:

1 For units which are designed to the *MOU Rules* corresponding requirements of the *MOU Rules* are to be applied.

ii) Commissioning Test Plan

A Test Plan is to be submitted to ABS at the start of the plan review process. The test plan is to identify all equipment and systems and is to include details of performance tests and trials for all operating modes. Tests for including testing of all automatic functions of the system including the power and energy management systems are to be included. Tests for the control, monitoring and safety system are also to be included to verify the system complies with 3/7.7, as applicable.

iii) Fuel Containment Inspection/Survey Plan

An inspection/survey plan for the fuel containment system (as applicable) is to be developed and submitted for approval by ABS. The inspection/survey plan is to identify components/systems to be examined and/or validated during each survey during the vessel's operating life.

iv) Operating Mode Trials Plan

- Each operating mode is to be subjected to trials in accordance with the approved trials plan required to be submitted for review before the trials. The trials plan is to specify the duration of tests and to include trials in all possible modes for full load testing, half load testing, reversing tests, maneuvering, and any other trials that may be applicable to the vessel, such as dynamic positioning, or wind turbine generator extreme condition shutdown, etc. During the trial, all functions of components, equipment, subsystems used in control, monitoring and safety systems of hybrid/all-electric power systems are to be tested in accordance with the provisions in 3/9.7.
- The trials plan is to include disconnection (emergency stop) of the energy storage system (ESS) (see Section 3/Table 4, item A8), as applicable for each operating mode. In the event of loss of the power supply provided by the ESS, the vessel's electrical supply system is to maintain power to equipment necessary for propulsion and steering and for the safety of the vessel.
- Operating modes testing are to be witnessed by Surveyor during harbor and Sea-trial.

1.7.2 Surveys During Installation *(1 April 2024)*

In general, the equipment is to be installed in accordance with the manufacturer's requirements as per the installation approved plans, and the ABS Rules as applicable,following are to be examined, verified and/or tested to the satisfaction of the attending surveyor:

i) All certified safe systems (as applicable) and instrumentation and control panels are to be verified to be in compliance with approved drawings.

ii) Electrical wiring and connections are to be in accordance with applicable Rules requirements of Section 4-8-4 of the *Marine Vessel Rules*, and Section 4-3-3 of the *MOU Rules*, and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) The Commissioning Test Plan is to be followed and verified by the Surveyor

v) For Wind and PV Solar structure installations, the NDT Inspection plans are to be available and verified by the Surveyor. See Subsection 5/3 (v), 5/5.3 and Subsection 5/7 (i), Wind (Subsection 6/3 (v), 6/5.3, and 6/7 (i)).

vi) For wind turbine installations with a slewing ring, a Rocking Test is to be performed once the wind turbine generator has been mounted, in accordance with the bearing manufacturer's instructions and the slew bearing clearances calculated from the results. The results are to be documented and made available to the attending Surveyor during annual and periodic surveys.

vii) Where applicable for PV Structure installation, random pull/loading tests are to be performed to satisfaction of the attending surveyor.

viii) Confirmation of removal of panels (e.g., PV solar) in emergency situation

ix) Confirmation of lowering wind turbine

x) Confirmation of removal of wind turbine blades

1.7.3 Surveys During Trials *(1 April 2024)*

During the initial trials, the hybrid electric power system/all-electric power system is to be verified for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the Operating Mode Trials Plan as per 7/1.7.

3 Surveys After Construction *(1 April 2024)*

3.1 General *(1 April 2024)*

Annual or Special surveys after construction are to be carried out for systems and equipment as referred below to the satisfaction of attending Surveyor, as applicable.

3.3 Annual surveys *(1 April 2024)*

The Hybrid/All-Electric Power System operating and maintenance records are to be examined to identify any issues with the power system.

If a hybrid fuel system is installed, the Hybrid Fuel Containment Inspection/Survey Plan is to be referenced and the fuel containment system examined.

If hybrid/all-electric systems are installed on deck such as wind turbine or solar PV panel arrays, the following are to be included during the Annual Survey as a minimum:

3.3.1 Wind Turbine *(1 April 2024)*

i) Wind turbine installations are to be examined as noted in 7-9-34/1.1.

ii) Verification that electrical equipment in hazardous locations has been properly maintained, including intrinsically safe and explosion-proof features of electrical equipment, and in particular any associated sealing equipment.

3.3.2 Solar PV *(1 April 2024)*

i) Visual inspection of the foundation structure members of the wind turbine or solar PV panel systems, as applicable, for deformation, excessive wear, corrosion, fractures, or damage.

ii) Visual inspection that means of protection from mechanical damage are maintained where enclosures or assemblies of electrical components or cables are located on deck.

iii) Verification that electrical equipment in hazardous locations has been properly maintained, including intrinsically safe and explosion-proof features of electrical equipment, and in particular any associated sealing equipment.

iv) Test of the ESD function.

v) Confirmation of no shading

vi) Confirmation of no hot spots

vii) Confirmation of cleaning panels

viii) Confirmation of measures to minimize solar glint/glare

The overall hybrid/all-electric power system is to be verified in acceptable condition and operational in all mode.

i) Through a review of the vessel's documentation and

ii) System testing in accordance with the Operating Mode Trials Plan when deemed necessary.

3.5 Special Surveys *(1 April 2024)*

In addition to the annual requirements in 7/3.3 above, the following hybrid/all-electric power systems are to be examined and tested to the satisfaction of the attending Surveyor:

3.5.1 Hybrid/All-Electric Power Systems *(1 April 2024)*

The tests are to be conducted in accordance with the Operating Mode Trials Plan, including:

i) Each operating mode is to be subjected to trials in accordance with the approved trials plan including trials in all possible modes for full load testing, half load testing, reversing tests, maneuvering, and any other trials that may be applicable to the vessel, such as dynamic positioning, or wind turbine generator extreme condition shutdown, etc.

ii) During the trials, all functions of components, equipment, subsystems used in control, monitoring and safety systems of hybrid electric power systems are to be tested in accordance with the provisions in 3/9.7 of the ABS *Requirements for Hybrid and All-Electric Power Systems for Marine and Offshore Applications*.

iii) The trials plan is to include disconnection (emergency stop) of the energy storage system (ESS) (see Section 3, Table 5, item A8) of the ABS *Requirements for Hybrid and All-Electric Power Systems for Marine and Offshore Applications*, as applicable for each operating mode.

iv) In the event of loss of the power supply provided by the ESS, the vessel's electrical supply system is to maintain power to equipment necessary for propulsion and steering and for the safety of the vessel.

3.5.2 Wind Turbine *(1 April 2024)*

Wind turbine installations are to be examined as noted in 7-9-34/1.3.

3.5.3 Solar PV *(1 April 2024)*

Confirmation of removal of panels (e.g., PV solar) in an emergency situation.

APPENDIX 1

Table for Cross References to existing ABS Requirements

1 General

1.1 Goals and Functional Requirements *(1 April 2024)*

The goals and functional requirements in the cross-referenced Rules, ABS Requirements Documents and ABS Guides are to be met.

1.2 Battery System Design and Construction *(1 April 2024)*

The provisions of this Section apply to vessel battery energy storage systems. The following references in Appendix 1/Table 1 are applicable to vessels designed, constructed, or retrofitted with a lithium-ion battery system used as an additional source of power with a capacity greater than 20 kWh. When batteries are being used as the main source of power, the additional requirements set forth in Section 4 of *Lithium-ion Batteries Requirements* are to be met.

TABLE 1
Lithium-ion Battery System Components *(1 February 2022)*

Battery System	*Lithium-ion Batteries Requirements Reference*
Battery System Components	Paragraph 2/1.3, Subsection 3/1
Battery Chargers	Subsections 2/3, 3/1
Battery Management Systems	Subsections 2/5, 3/1
Battery System Installation	Section 3
Battery System Used as Main Source of Electrical Power	Section 4
Battery System Surveys	Section 5

1.3 Supercapacitor System Design and Construction

The provisions of this Section apply to vessel supercapacitor energy storage systems. The following references in Appendix 1/Table 2 are applicable to vessels designed, constructed, or retrofitted with a supercapacitor system used as an additional source of power with a capacity greater than 50 Wh.

TABLE 2
Supercapacitor System Components

Supercapacitor System	*Supercapacitor Requirements Reference*
Supercapacitor Cells/Modules	Subsection 2/3, 3/1.1, 3/1.3
Supercapacitor Chargers	Subsection 2/5, 3/1.5
Supercapacitor Management Systems	Subsection 2/7, 3/1.5
Supercapacitor Converters	Subsection 2/5, 3/1.5
Supercapacitor System Testing and Installation	Section 3
Supercapacitor System Surveys	Section 4

1.5 Fuel Cell Power System Design and Construction

The provisions of this Section apply to vessel fuel cell power systems using a gaseous fuel as well as liquid fuels. The following references in Appendix 1/Table 3 are applicable to vessels designed, constructed, or retrofitted with a fuel cell used for auxiliary and main electric power systems.

TABLE 3
Fuel Cell Power System Components

Fuel Cell Power System	*Fuel Cell Power System Requirements Reference*
Materials	Subsection 2/2
Fuel Cell Module	Subsection 2/4
Arrangements and Installation	Section 3
Fire Safety	Section 4
Electrical Systems	Section 5
Control, Monitoring and Safety Systems	Section 6
Fuel Cell Power System Surveys	Sections 7 and 8

APPENDIX 2

Hybrid Electric Power Systems Installed On Board Yachts

1 General

1.1 Goals and functional Requirements *(1 April 2024)*

The goals and functional requirements in the cross-referenced Rules, ABS Requirements Documents and ABS Guides are to be met.

1.2 Application

The provisions of this Appendix apply to the design, construction, and testing of hybrid electric power systems intended for installation on yachts. Compliance with the requirements in this Appendix is to be verified by ABS.

3 Plans and Data to be Submitted

i) All plans and data as requested by 2/1.3 and 2/1.5 of this document are to be submitted.

ii) All plans and data as required by 4-6-2/1, 4-6-3/1, 4-6-4/1.3 and 4-6-5/3.1.2 of the *Yacht Rules* are to be submitted.

5 Certification *(1 April 2024)*

The following Table 1 provides the applicability of the certification requirements for certain equipment and components as referred to in Part 4 and applicable Chapters and Sections of the *Yacht Rules*.

See 4-1-1/Table 3C of the *Yacht Rules*.

7 Onboard Documentation

See Subsection 2/5, as applicable.

9 System Design

See Section 3, as applicable.

11 Electrical Equipment and Installation

i) See applicable Sections of Part 4, Chapter 6 of the *Yacht Rules.*

ii) See also Section 4 of this document, as applicable.

iii) Material for gears and gear units is to be designed in accordance with 4-3-1/3 of the *Marine Vessel Rules*.

13 Tests and Trials

13.1 Surveys During Construction

13.1.1 Surveys at Manufacturer's Facility *(1 April 2024)*

See 4-1-1/Table 3C of the *Yacht Rules* and Section 2/Table 2 of this document for certification requirements for Yachts. Survey requirements for equipment components at the manufacturer's facility are summarized in the applicable sections of the *Yacht Rules.*

i) The manufacture, testing, inspection, and documentation of the power system is to be in accordance with applicable ABS Rules, recognized standards and the requirements given in this Section.

ii) At the option of the manufacturer, each machine design or type may be enrolled in the ABS Type Approval Program in accordance with the provisions of 1-1-A3/5.1 of the ABS *Rules for Conditions of Classification (Part 1)*. The details of the ABS approval may be posted on the ABS website, http://www.eagle.org/typeapproval.

13.1.2 Tests for Control, Monitoring and Safety System

i) Equipment in association with control, monitoring and safety systems of the hybrid electric power generating plant for Yachts installations are to be performance tested in accordance with 4-7-2/Table 1 of the *Yacht Rules*, as applicable.

ii) Indications of parameters necessary for the safe and effective operation of the control, monitoring and safety system are to be tested and verified according to 3/9.7 of this document, as applicable.

iii) Simulation testing for verification of the systems/equipment integration may be performed as per Subsection 3/23 of this document.

13.1.3 Onboard Testing *(1 April 2024)*

i) General

- Onboard testing is to verify that functionality has been achieved with all systems in operation.
- The hybrid/all-electric power system installations, as appropriate, are to be examined and tested to the satisfaction of the attending Surveyor in accordance with the approved plans.
- All requirements applicable electrical equipment installation on board vessels are given in Section 4-6-3 of the *Yacht Rules*.

ii) Commissioning Test Plan

A Test Plan is to be submitted to ABS at the start of the plan review process. The test plan is to identify all equipment and systems, including details of performance tests and trials for all operating modes, including testing of all automatic functions of the system including the power and energy management systems. Tests for the control, monitoring and safety system are to be included to verify the system complies with 3/7.7, as applicable.

iii) Fuel Containment Inspection/Survey Plan

An inspection/survey plan for the fuel containment system (as applicable) is to be developed and submitted for approval by ABS. The inspection/survey plan is to identify components/systems to be examined and/or validated during each survey during the vessel's operating life.

iv) Operating Mode Trials Plan

- Each operating mode is to be subjected to trials in accordance with the approved trials plan required to be submitted for review before the trials. The trials plan is to specify the duration of tests and to include trials in all possible modes for full load testing, half load testing, reversing tests, maneuvering, and any other trials that may be applicable to the vessel, such as dynamic positioning etc. During the trial, all functions of components, equipment, subsystems used in control, monitoring and safety systems of hybrid electric power systems are to be tested in accordance with the provisions in 3/7.7.
- The trials plan is to include disconnection (emergency stop) of the energy storage system (ESS) (see Section 3/Table 4, item A8), as applicable for each operating mode. In the event of loss of the power supply provided by the ESS, the vessel's electrical supply system is to maintain power to equipment necessary for propulsion and steering and for the safety of the vessel.
- Operating modes testing are to be witnessed by Surveyor during harbor and Sea-trial.

13.1.4 Initial Survey *(1 April 2024)*

i) Surveys During Installation

- The equipment is to be installed in accordance with the manufacturer's requirements as per the installation approved plans, and the *Yacht Rules* as applicable.
- All certified safe systems (as applicable) and instrumentation and control panels are to be verified to be in compliance with approved drawings.
- Electrical wiring and connections are to be in accordance with applicable *s* requirements of Section 4-6-2 of the *Yacht Rules* and checked for continuity and proper workmanship.
- Instrumentation is to be tested to confirm proper operation as per its predetermined set points.
- The Commissioning Test Plan is to be followed and verified by the Surveyor

ii) Surveys During Trials

During the initial trials, the system is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the Operating Mode Trials Plan as per A2/13.1.3 iv) of this document.

13.3 Surveys After Construction

13.3.1 General *(1 April 2024)*

Surveys after construction are to be carried out in accordance with the ABS *Rules for Surveys After Construction (Part 7)* as applicable.

Annual or Special surveys after construction are to be carried out to for systems and equipment as referred to in A2/13.3.2 and A2/13.3.3 below, as applicable.

13.3.2 Annual Surveys *(1 April 2024)*

The Power System operating and maintenance records are to be examined to identify any issues with the system. If a hybrid fuel system is installed, the Hybrid Fuel Containment Inspection/ Survey Plan is to be referenced and the fuel containment system examined. The overall power system is to be verified in acceptable condition and operational in all modes through a review of the vessel's documentation and system testing in accordance with the Operating Mode Trials Plan when deemed necessary.

13.3.3 Special Surveys *(1 April 2024)*

Dock trials are to be conducted to verify the proper operation of the power system in all operational modes. Testing conducted is to be done using the Operating Mode Trials Plan as guidance.