

Guide for

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# Hybrid Electric Power Systems for Marine and Offshore Applications



February 2022



GUIDE FOR

...  
**HYBRID ELECTRIC POWER SYSTEMS FOR MARINE AND  
OFFSHORE APPLICATIONS  
FEBRUARY 2022**

American Bureau of Shipping  
Incorporated by Act of Legislature of  
the State of New York 1862

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## Foreword (1 February 2022)

ABS has developed a series of Guides for hybrid electric technologies (*Lithium-ion Batteries Guide*, *Supercapacitor Guide*, *Fuel Cell Power Systems Guide*, *DC Power Distribution Guide*, etc.). 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 Guide focuses on the integration of those new technologies with conventional power generation to develop a hybrid electric power system (HEPS).

A HEPS utilizes multiple sources of power, both non-traditional sources (e.g. batteries, super-capacitors, fuel cells) and traditional sources (e.g. internal combustion engine driven generator sets, shaft generator driven by main engine). Technological developments are constantly being introduced for electric power systems. It is expected that other alternate electrical power sources such as solar panels, flywheels, and wind (electric) power systems will be mature enough for integration into the electric power generation systems onboard vessels. Vessels with such arrangements also incorporate specialized power and energy management systems that are relatively new in the industry. The application of HEPS onboard the vessel **may help** to reduce NO<sub>x</sub>, SO<sub>x</sub> and CO<sub>2</sub> emissions.

Current trends in the yacht industry have also resulted in increased demand for hybrid electric installations. This Guide introduces requirements for the design, installation, and testing of HEPS on yachts.

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 association with this Guide.

The February 2022 edition incorporates 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 added into the new 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 support Section 5 and Section 6 related to wind and solar PV electric power generating systems.

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

Users are advised to check periodically on the ABS website [www.eagle.org](http://www.eagle.org) to verify that this version of the Guide is the most current.

*We welcome your feedback. Comments or suggestions can be sent electronically to [rsd@eagle.org](mailto:rsd@eagle.org).*



GUIDE FOR

# HYBRID ELECTRIC POWER SYSTEMS FOR MARINE AND OFFSHORE APPLICATIONS

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## 1 Introduction

For the last 60 years, the primary form of ship propulsion consisted of diesel engines delivering thrust directly to the water via a shaft and propeller.

However, with current 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 motors. These propulsion motors are powered by a set of generators which supply both the vessel's essential and non-essential service loads.

Hybrid electric power systems offer the opportunity to improve safety, reliability, operational efficiency, and reduce the fuel consumption, environmental footprint, and equipment maintenance when compared to traditional electrical power systems.

This Guide provides requirements for the design, construction, testing and survey of vessels utilizing hybrid electric power systems.

## 3 Application and Scope

### 3.1 Application (1 February 2022)

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

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

### 3.3 Scope (1 February 2022)

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

The integration of these conventional power generation and alternate power sources on a vessel or unit is also known as the Integrated Electric Power System (IEPS) for the purpose of this Guide.

The integrated electric power system is utilized for powering the vessels or units' essential and/or non-essential service loads.

The unique requirements for the design, installation, and testing of HEPS on yachts are also addressed.

The scope of this Guide also encompasses HEPS with integration of lithium-ion battery systems, supercapacitor systems, and fuel cell power systems as detailed in the applicable ABS Guides as referenced in 1/11.1.

## 5 Classification Symbols and Notations

### 5.1 Notations

#### 5.1.1 Hybrid Notations for Marine and Offshore Vessels (1 February 2022)

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

*i)* **HYBRID IEPS** Notation

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

*ii)* Descriptive Letters for Operating Modes

Where a vessel is arranged to comply with 1/5.1.1i) above, and is also fitted with means to operate under one or more specific operating modes as identified in Section 3/Table 2, the vessel **may** be assigned the Class Notation **HYBRID IEPS** and **[descriptive letters, describing operating modes]**, e.g. **HYBRID IEPS [LEE]**, **HYBRID IEPS [PMT]**, etc.

*Notes:*

- 1 The combination of two or more new technologies (e.g. ESS and Fuel Cells) when conventional generation is not installed on board also constitutes a HEPS; therefore, these vessels can have the **HYBRID IEPS** notation.
- 2 Internal combustion engine driven generator sets and shaft generators by themselves alone do not meet the criteria for **HYBRID IEPS**.

### 5.3 Notation Scheme Designation

The optional notation is organized as denoted in Table 1 below.

**TABLE 1**  
**Designation Scheme of Notations**

<i>Notation</i>	<i>Enhanced Notation [operating mode]</i>
<b>HYBRID IEPS</b>	<b>HYBRID IEPS [descriptive letters, describing operating modes]</b>

*Note:*

Operating Modes: Low-Exhaust Emission **[LEE]**, Power Management **[PMT]**, Power Backup **[PBU]**, Power Take-Off/Power Take-In **[PTO/PTI]**, Shore Connection **[SCN]**

## 7 Terminology (1 February 2022)

*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 a monitoring circuitry that provides information to a battery system. [IEC 62620]

*Battery System (Array).* 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.* 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.* Device capable of reducing the rotor speed or stopping rotation of a wind turbine system.

*Bypass Diode.* 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 Guide).

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

*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 Guide 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.* 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 Fuel Cell is 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.

*Integrated Electric Power System (IEPS).* Is 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.

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

*Hot Spot.* Intense localized heating occurring 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 and must 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 (HEPS).* 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. The architecture of a hybrid system can be designed specifically for the requirements of each vessel and thus optimize the use of each component for maximum efficiency. The combination of two or more new technologies when conventional generation is not installed on board also constitutes a HEPS.

*Maximum Power Point Tracking (MPPT).* 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 strategy is to store energy during low periods of power demand and release during high peaks of power demand (typically by the ESS).

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

*Photovoltaic Module.* Complete and environmentally protected assembly of interconnected photovoltaic cells.

*Photovoltaic Module Junction Box.* 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.* Circuit of series-connected PV modules.

*Photovoltaic System.* 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 Mode.* It is 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 availability of 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) provide 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 Guide the PMS can also have similar functionalities as an EMS.

*Power Management Mode.* This mode is designated when different load schedule strategies, functions, load control strategies such as load sharing and load shedding are met through the PMS installed onboard the vessel or unit.

*Power Take-In (PTI) Mode.* The shaft generator functions as an auxiliary motor working concurrently with the main diesel engine or independently for electric propulsion in this mode. This is 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).

*Small Wind Turbine.* System of 200 m<sup>2</sup> rotor swept area or less that converts kinetic energy in the wind into electrical energy. *Note:* A small wind turbine system includes the wind turbine itself including support structures, the turbine controller, the charge controller / inverter (if required), wiring and disconnects, the installation and operation manual(s) and other documentation.

*State of Charge (SOC).* 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 Vessels Rule*.

*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.

*Low Exhaust Emission Mode.* 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.

## 9 Abbreviations and Acronyms (1 February 2022)

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

<i>ABS</i>	American Bureau of Shipping
<i>BMS</i>	Battery Management System
<i>BoD</i>	Basis of Design
<i>CMS</i>	Capacitor Management System
<i>DPS</i>	Dynamic Positioning System
<i>EG</i>	Emergency Generator
<i>EMS</i>	Energy Management System
<i>ESS</i>	Energy Storage System
<i>ETD</i>	Energy Transformation Device
<i>ETS</i>	Energy Transformation System
<i>ESD</i>	Emergency Shutdown
<i>FC-CMSS</i>	Fuel Cell Control, Monitoring, Safety System
<i>FC-PS</i>	Fuel Cell Power System
<i>GENSET</i>	Diesel Generator or Generator together with Prime-mover
<i>HEPS</i>	Hybrid Electric Power System
<i>IEC</i>	International Electrotechnical Commission
<i>IEPS</i>	Integrated Electric Power System
<i>IC</i>	Internal Combustion
<i>NDT</i>	<i>Nondestructive Testing</i>
<i>PEC/PCE</i>	Power electronic converters/ <b>Power conversion equipment</b>
<i>PMS</i>	Power Management System

<i>PTI</i>	Power Take In
<i>PTO</i>	Power Take Off
<b>PV</b>	<b>Photovoltaic</b>
<i>SCMS</i>	Supercapacitor Management System
<i>SOC</i>	State of Charge
<i>SOLAS</i>	<i>The International Convention on the Safety of Life at Sea</i>
<i>UL</i>	Underwriters Laboratories
<i>UPS</i>	Uninterruptible Power Systems

## 11 References

### 11.1 ABS (1 February 2022)

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

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

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

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

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

*ABS Guide for High Voltage Shore Connection (HVSC Guide)*

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

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

*ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas 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 Guide for Wind Assisted Propulsion System Installation*

*ABS Guide for Crew Habitability*

### 11.3 IEC References (1 February 2022)

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*

### 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

Hybrid electric power systems may comply with the requirements of an alternative standard, in lieu of the specific requirements in the Guide, 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 the Guide. In all cases, the hybrid 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

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 electric power system (HEPS) is requested, applicants should 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 1 and 2 & Appendix 2/ Table 1 of this Guide for certification details. Alternative certification arrangements are also available in 1-1-A3/5.5 of the *ABS Rules for Conditions of Classification (Part 1)*.

## SECTION 2 Plans and Data to be Submitted

### 1 System documents and plans to be submitted

#### 1.1 General (1 February 2022)

In general, for vessels using any combination of two or more the following power sources, documentation showing optimization calculations/ results for sizing the HEPS is to be submitted to ABS for review.

The combination can be conventional generation<sup>(1)(2)</sup> and new technology<sup>(3)</sup>, or two or more new technologies.

- i) Internal combustion engine (Diesel/ dual fuel/gas) driven electric generators <sup>(1)</sup>
- ii) Power Take-Off (Shaft Generators) <sup>(1)</sup>
- iii) Fuel cells
- 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\_IEPS.
- 3 New technology for power generation can include low- or zero- emission power generation systems such as solar PV arrays or wind turbines.

#### 1.3 HYBRID IEPS Submissions (1 February 2022)

- i) For general requirements for documentation related to battery power system design, see Subsection 1/13 of ABS *Guide for use of Lithium-ion Batteries in the Marine and Offshore Industries (Lithium-ion Batteries Guide)*.
- ii) For general requirements for documentation related to supercapacitor power system design, see Subsection 1/13 of ABS *Guide for use of Supercapacitors in the Marine and Offshore Industries (Supercapacitor Guide)*.
- iii) For general requirements for documentation related to fuel cell power system design, see Subsection 1/9 of ABS *Guide for Fuel Cell Power System for Marine and Offshore Applications (Fuel Cell Guide)*.

- iv)* A description of the PMS, including location and arrangement plan.
- v)* Arrangements, details, and location of the propulsion control consoles and or panels including schematic diagrams of the system therein.
- vi)* Arrangements and details of the semiconductor converter enclosure for propulsion system, where applicable, including cooling system with its interlocking arrangement.
- 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 onboard). See also Section 3/15.
- viii)* General Arrangement of power distribution system including energy storage system.
- ix)* Fuel consumption data in various operating modes, as applicable, for record .
- x)* Calculations for sizing energy storage system (ESS), e.g. battery selection, type and size, etc.
- xi)* Basis of design and or specifications of integration of control systems, EMS, PMS, BMS, SCMS, ESS, etc.
- xii)* 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.
- xiii)* Operations and maintenance manual.
- xiv)* Test plans required for the testing listed in 7/1.7i.
- xv)* Commissioning Test Plan required by 7/1.7ii.
- xvi)* Fuel containment inspection plan required by 7/1.7iii.
- xvii)* Operating Mode Trials Plan required by 7/1.7iv.
- xviii)* Emergency shutdown (ESD) arrangement.
- xix)* 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
- xx)* Ventilation arrangement of energy storage space including fire dampers, emergency shutdown from outside space.
- xxi)* List of minimum alarms/displays and shutdowns as required in Section 3/Table 4.
- xxii)* 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.
- xxiii)* Details of piping system and components associated with the hybrid/ESS systems, where applicable.
- xxiv)* Manufacturer's recommendation regarding HEPS equipment's service life and inspection cycles (e.g. ESS', fuel cell's, etc.). See 3/1.5.1.
- xxv)* Designer's documentation (e.g. estimation/calculations) regarding HEPS equipment/system's integration service life (e.g. ESS', fuel cell's, etc.) considering the overall configuration. See 3/1.5.1.
- xxvi)* Modeling, simulation, and the detailed results are to be submitted as applicable for review as required in 3/19.3 of this Guide.
- xxvii)* A list/booklet identifying all electrical equipment installed in the hazardous areas, as applicable.

### 1.5 HYBRID IEPS [Operating Mode] Submissions

In addition to 2/1.3 above, the following are to be submitted:

- i) System arrangement and associated drawings and information for each operating mode as applicable.
- ii) A list of any additional alarms, monitoring and safeguards for each operating mode as applicable.
- iii) Overload and load shedding arrangement.
- iv) Arrangements and details of shaft generator electric coupling/clutch, where applicable.
- v) Control strategy and detail arrangements for the interconnection of ESS, FC, SC, and conventional generators (including shaft generator) for the different operating modes and operation profiles.

### 1.7 Yacht Submissions

- i) Paragraphs 2/1.3 and 2/1.5 above as applicable.
- ii) See also Appendix 2/3.

### 1.9 Solar Photovoltaic Electric Power Generation Submissions (1 February 2022)

- i) Paragraphs 2/1.3 and 2/1.5 above as applicable.
- ii) See additional submittal items in Subsection 5/3

### 1.11 Wind Electric Power Generation Submissions (1 February 2022)

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

## 3 Certification

Hybrid electric power systems are to be certified in accordance with Section 2/Table 1 and Section 2/Table 2 below. This table also provides 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 1**  
**Hybrid Electric Power System Certification<sup>(4)</sup>**

<i>System, Equipment, Component</i>	<i>ABS Certification<sup>(1)</sup></i>	<i>ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>Rule (Marine Vessel Rules) Reference</i>
Power Transformers for Essential Service and for Emergency Source Power and Convertors of Low Voltage		1	MVR 4-8-3/7, 4-8-3/8
Power Transformers and Convertors for High Voltage System	Required	5	MVR 4-8-5/3.7.5(e)
Non-Sparking Fans		2	MVR 4-8-3/11
Other Electrical Equipment	Required	1/2/4/5	MVR 4-8-3, 4-1-1/Table 3 as applicable
Other Rotating Machines	Required	1/2/4/5	MVR 4-8-3, 4-1-1/Table 3 as applicable

<i>System, Equipment, Component</i>	<i>ABS Certification<sup>(1)</sup></i>	<i>ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>Rule (Marine Vessel Rules) Reference</i>
Propulsion Generators	Required	5	MVR 4-8-3/3, 4-1-1/Table 3, 4-8-5/5.17.5
Shaft Generators & Propulsion Motors <sup>(3)</sup>	Required	5	MVR 4-3-2/1.5, 4-8-3/3, 4-8-5/5.17.5
Pipe, Valves and Fitting	Required <sup>(2)</sup>	1/2/4/5	MVR 4-6-1, 4-1-1/Table 6 as applicable

**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.

**TABLE 2**  
**Hybrid Electric Power System Certification (1 February 2022)**

<i>System, Equipment, Component</i>	<i>ABS Certification<sup>(1)</sup></i>	<i>ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>Guide Reference</i>
Battery System Components	Required	4/5	Section 2/Table 1 of <i>Lithium-ion Batteries Guide</i>
Battery Chargers	Required	4/5	Section 2/Table 1 of <i>Lithium-ion Batteries Guide</i>
Battery Management Systems	Required	4/5	Section 2/Table 1 of <i>Lithium-ion Batteries Guide</i>
Supercapacitor Cells/ Modules	Required	4/5	Section 2/Table 1 of <i>Supercapacitor Guide</i>
Supercapacitor Chargers	Required	4/5	Section 2/Table 1 of <i>Supercapacitor Guide</i>
Supercapacitor Management Systems	Required	4/5	Section 2/Table 1 of <i>Supercapacitor Guide</i>
Supercapacitor Converters	Required	2	Section 2/Table 1 of <i>Supercapacitor Guide</i>
Fuel Cell Modules	Required	4/5	Section 1/Table 3 of <i>Fuel Cell Guide</i>

<i>System, Equipment, Component</i>	<i>ABS Certification<sup>(1)</sup></i>	<i>ABS Type Approval Tier (See Appendix 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>Guide Reference</i>
Fuel Cell Power System	Required <sup>(2)</sup>	4/5	Section 1/Table 3 of <i>Fuel Cell Guide</i>
Fuel Cell Control and Monitoring System	Required	4/5	Section 1/Table 3 of <i>Fuel Cell Guide</i>
Solar PV Electric Power Generating Systems	Required <sup>(3)</sup>	See Note 3	Section 5/5.1 Table 1 of this Guide
Wind Electric Power Generating Systems	Required <sup>(3)</sup>	See Note 3	Section 6/5.1 Table 1 of this Guide

**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 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.
- 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.).

## 5 Onboard Documentation

### 5.1 General (1 February 2022)

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, FC-CMSS, etc.
- ii) Hybrid electric power system operations and maintenance manual
- iii) Hybrid electric power system functional test schedules
- 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

## 1 Design Principles & System Configuration

### 1.1 General

Hybrid electric power systems incorporate multiple sources of power, usually a combination of both non-traditional sources (batteries, capacitors, and fuel cells) and traditional sources (gas, diesel, and dual fuel internal combustion engine driven generators). The design, construction, installation testing and maintenance is to be in general in accordance with this Guide, the *ABS Rules for Building and Classing Marine Vessels*, the *Mobile Offshore Units Rules*, or other ABS Guides applicable to the type of vessel or installation under consideration.

For vessels, the applicable Parts of the *Marine Vessel Rules* are:

- Part 4, Chapter 8, Electrical Systems
- Part 4, Chapter 9, Automation

For offshore units, the applicable Parts of the *Mobile Offshore Units Rules* are:

- Part 4, Chapter 3, Electrical Installations

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

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

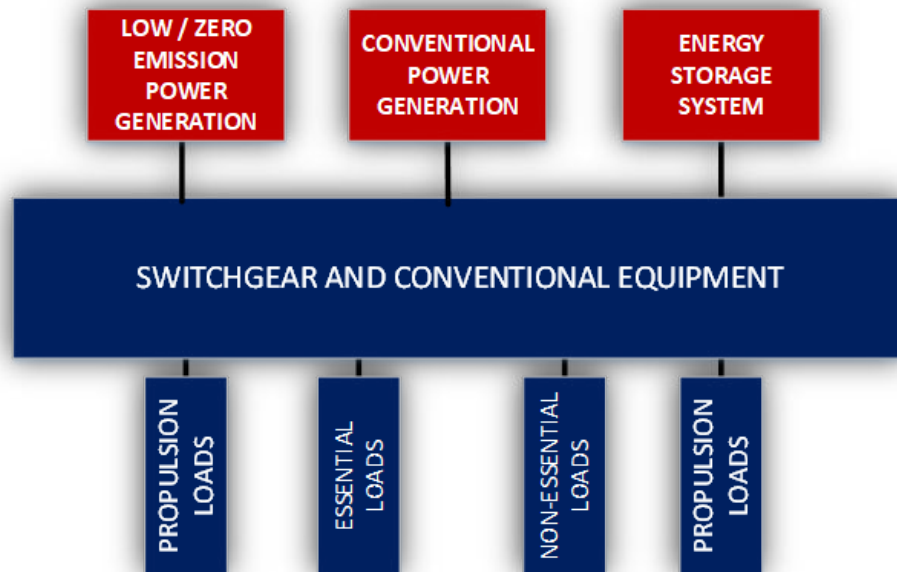
When an ESS is being proposed as an emergency source of electric power, consideration will be given in a case-by-case basis, provided all requirements of 4-8-2/5 of the *Marine Vessel Rules* are complied with as applicable.

### 1.3 Main Source of Electrical Power

#### i) Integration of Different Technologies

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

**FIGURE 1**  
**Integration of Different Sources of Power Generation and Driven Loads**



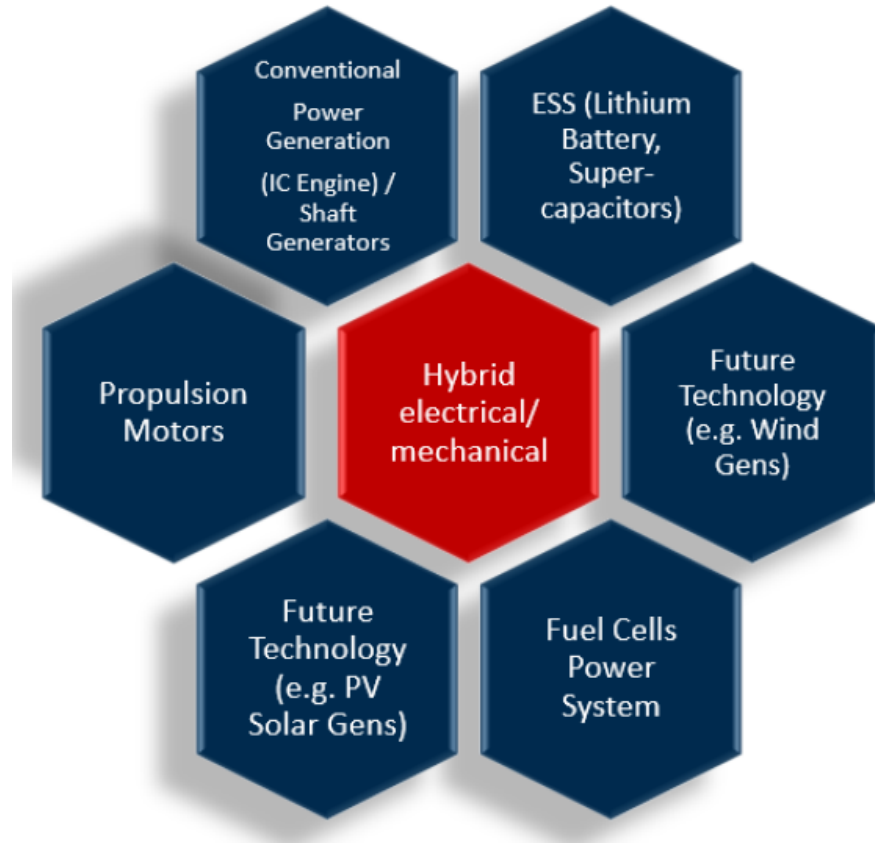
*ii)* Selection of Electric Source of Power and Energy Storage Systems

Different types of power generation and ESS sources contribute to the hybrid electric power system (HEPS). These provide electrical power to the ship's service electrical loads and the electric motor driven propulsion loads of the vessel or unit. See Figure 2.

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



**FIGURE 2**  
**Combination of Different Type of Power Generation, Energy Sources, and Driven Loads**



**1.5 Generation and Energy Storage Systems Capacity**

**1.5.1 General (1 February 2022)**

The energy transformation devices (ETD) and the energy storage systems (ESS) are to be selected and sized accordingly in order to enable the HEPS to operate and provide the functionality that is required for, without damage throughout its service life.

In the event that 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 should be selected and sized based upon the capacity and performance of the ESS expected towards the end of its life.

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

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

	<i>Applicable System</i>	<i>Guide Reference</i>
ESS	Lithium-ion Batteries - Battery Management System (BMS)	<i>ABS Guide for Use of Lithium-ion Batteries in the Marine and Offshore Industries</i>
	Supercapacitors - Capacitor Management System (CMS)	<i>ABS Guide for Use of Supercapacitors in the Marine and Offshore Industries</i>

	<i>Applicable System</i>	<i>Guide Reference</i>
ETD	Fuel Cell Power System	<i>ABS Guide for Fuel Cell Power System for Marine and Offshore Applications</i>
	Solar PV Electric Power Generation System	See Section 5 of this Guide
	Wind Electric Power Generation System	See Section 6 of this Guide

### 3 Operating Modes

#### 3.1 General

The operational requirements of the HEPS 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 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 Section 3/Table 2.

Expected fault conditions and mitigation plans are to be identified during the risk analysis phase of the project and included in accordance with Section 3/15 of this Guide.

#### 3.3 Operating Modes Capabilities

##### 3.3.1 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 IEPS [operating mode]** notation.

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

##### 3.3.2 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 onboard and their functionalities and arrangements.

**TABLE 2**  
**Hybrid Operating Modes <sup>(1)</sup>**

	<i>Operating Mode</i>	<i>Functionalities / Arrangements</i>	<i>Enhanced Notation</i>
1	Low Exhaust Emission	<ol style="list-style-type: none"> <li>1. Electrical power supplies the ship's consumers and main propulsion system by ESS and/or FC-PS</li> <li>2. Engine driven gensets are off (e.g. at Port)</li> <li>3. Boilers and incinerators operating on liquid fuel are to be off (e.g. at Port)</li> <li>4. Specific time limit (vessel operating on ESS) is to be specified.</li> </ol>	<b>HYBRID IEPS [LEE]</b>
2	Power Management	<ol style="list-style-type: none"> <li>1. Typical schedule strategies:               <ol style="list-style-type: none"> <li>1.1 Peak Shaving</li> <li>1.2 Load Leveling/ load smoothing</li> </ol> </li> <li>2. Load sharing control</li> <li>3. Load shedding/ preferential trips</li> <li>4. Blackout prevention</li> <li>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.</li> </ol>	<b>HYBRID IEPS [PMT]</b>
3	Power Backup	<ol style="list-style-type: none"> <li>1. The ESS is to be readily available to the ship's electrical system during a contingency (e.g. loss of a conventional generator).</li> <li>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 HEPS stability (not loss of HEPS' frequency).</li> <li>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.</li> </ol>	<b>HYBRID IEPS [PBU]</b>

	<i>Operating Mode</i>	<i>Functionalities / Arrangements</i>	<i>Enhanced Notation</i>
4	PTO/PTI <sup>(2)</sup>	<p>1. Power Take Off (PTO): Operating mode where a shaft generator provides electrical power flow to the ship's electrical network.</p> <p>2. Power Take In (PTI): Operating mode where a shaft generator operates as a motor to boost the main propulsion engine power.</p>	<b>HYBRID IEPS [PTO/PTI]</b>
5	Shore Connection <sup>(3)</sup>	<p>1. When the vessel is provided with a shore connection installation in accordance with the <i>MVR Rules</i> or a high voltage shore connection in accordance with the <i>ABS HVSC Guide</i>.</p> <p>2. The modes of operation related to the shore connection and hybrid is:</p> <p><i>a)</i> The shore connection is arranged for charging the onboard ESS while providing power to the vessel's electrical consumers, And/or</p> <p><i>b)</i> 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 shall be monitored, with alarms, to prevent hidden failure when shore power is disconnected).</p> <p>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).</p>	<b>HYBRID IEPS [SCN]</b>

**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 alone do not meet the criteria for HYBRID IEPS.
- 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 should 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.

### 3.3.3 Power Management System Functionalities

#### *i) General*

In general, a PMS is to be provided in accordance with applicable Sections of the *Marine Vessel Rules* Part 4, Marine Systems and Machinery, and applicable ABS Guides.

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

For vessels using combination of any diesel electric generators (and a shaft driven motor/generator {PTO/PTI}), and energy storage system, and/or fuel cells, fuel consumption and emissions optimization and calculation process for sizing the HEPS (propulsion system and electric power supply system) is 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.

## 5 Power Distribution System

### 5.1 Power Quality

*i)* In general, electrical power quality of the HEPS 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 ABS *Marine Vessel Rules*:

Part 4, Chapter 8, Electrical Systems

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

*ii)* In cases 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 HEPS integration's modeling and simulation process prior to system/equipment installation, in this regard results from this process is expected to be submitted to ABS for review.

### 5.3 ESS Categorization based on Usage

The ESS can be used to serve essential loads (including emergency loads) and non-essential loads in accordance with ABS *Marine Vessel Rules* and ABS *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 4-3-1/3.5 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.

## 7 Control and Instrumentation

### 7.1 General

The HEPS' control system as referred 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.

In general, 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 *MVR*, the *MOU Rules*, or other ABS Guides as appropriate for the type of vessel or installation under consideration. See references in 1/1.11.

### 7.3 Power Management System (PMS)

For power management system and functionalities, see 3/3.3.3.

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 Section 3/ Table 4.

### 7.5 Energy Management System (EMS)

#### i) General

The HEPS vessels typically have an integrated hybrid electric power system and an energy management control system. The energy management control system is built with an operation strategy to control and supervise the different subsystems the HEPS 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. Table 3 refers to the applicable management technologies as per ABS Guides and ABS Rules.

**TABLE 3**  
**Energy/ Power Management Systems (1 February 2022)**

<i>Example of ESS, ETD Management Systems</i>	<i>Rule &amp; Guide Reference</i>
Battery System Components (BMS)	2/1.3, Subsection 3/1 of <i>Lithium-ion Batteries Guide</i>
Supercapacitor Management Systems (CMS)	Subsection 2/7, 3/1.5 of <i>Supercapacitor Guide</i>

<i>Example of ESS, ETD Management Systems</i>	<i>Rule &amp; Guide Reference</i>
Fuel Cell Control, Monitoring and Safety Systems (FC-CMSS)	Section 6 of <i>Fuel Cell Guide</i>
Power Management System (PMS)	4-8-5/5.3.3 of <i>Marine Vessel Rules, Dynamic Positioning System Guide</i>

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 Section 3/Table 4.
- Upon failure of the power management system, the available electrical power is to remain unchanged. Failure of the power management system is to be alarmed at a manned control station.

### 7.7 Control, Monitoring, Alarm and Safety Systems

- i)* The HEPS 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)
  - b)* Engine control room (or offshore propulsion centralized control station)
  - 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 & shutdown is provided in Table 4 below.

**TABLE 4**  
**List of Alarms and Shutdown (1 February 2022)**

<i>Systems</i>	<i>Monitored Parameters</i>		<i>A &amp; D</i>	<i>Auto Shut down <sup>(1)</sup></i>	<i>Notes</i> [ <i>A = Alarm; D = Display;</i> <i>x = applies</i> ]
Energy Storage System <sup>(3)/(4)</sup>	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) <sup>(5)</sup>	x	x	
	A7	Cooling or fan - failure	x	x	
	A8	Emergency Stop <sup>(2)</sup>	x	x	See 7/1.7.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 4/1.5
Energy Management System (EMS)	D1	Failure System	x		See Table 3 of 3/7.5
Battery Management System (BMS)	D2	Failure System	x		See Table 3 of 3/7.5, if fitted
Supercapacitor Management Systems (CMS)	D3	Failure System	x		See Table 3 of 3/7.5, if fitted
Fuel Cell Control, Monitoring and Safety Systems (FC-CMSS)	D4	Failure System	x	x	See Table 3 of 3/7.5, Section 6/ Table 1 of ABS <i>Fuel Cell Guide</i> , if fitted
Power Management System (PMS)	D5	Failure System	x		See Table 3 of 3/7.5, if fitted



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

**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 Guide (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 Electrical Protection System

In general, the HEPS protection and control system is to be in accordance with the different requirements as specified in the ABS *Marine Vessel Rules*.

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

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

- i) For protection zones defined by power electronic devices (PEMs), the ABS *Guide 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 the AC and DC distribution system, methods of calculations of fault currents and protection coordination methodologies are 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 Vessels Rules*.

## 11 Equipment Earthing

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

## 13 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 Section 4-8-3/TABLE 2, and 4-8-4/1.3 of the *Marine Vessels Rules*.

## 15 HEPS Risk Assessment

### 15.1 General

- 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 onboard. 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 should be given to aligning these studies with modeling and simulation efforts.

### 15.3 Risk Assessment Techniques

- i) The use of risk assessment techniques should 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.

## 17 Emergency Source of Power (1 February 2022)

- i) In general, conventional diesel engine driven emergency generators are to comply with applicable Sections of the *Marine Vessel Rules*, and the *MOU Rules*.
- ii) When an ESS (e.g. lithium-ion batteries) is being proposed as an emergency source of electric power, consideration will be given on a case-by-case basis, provided all requirements Subsection 4-8-2/5 of the *Marine Vessel Rules* are complied with, or 4-3-2/5.3 of the *MOU Rules*, as applicable, are complied with.

## 19 Modeling and Simulation

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.

### 19.1 General

- i)* Modeling and simulation of the HEPS 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

### 19.3 Documents to be submitted

- i)* Model of the HEPS that has been developed in a simulation space that supports the functional mockup interface (FMI) standard.
- ii)* Report of the results of the execution of the simulation of the HEPS model depicting steady state operation, switching operation, transient operation, and fault operation of the power system. The simulation results should be provided in a format that will be capable of comparison to simulation performed independently on alternative simulation software.
- iii)* Short circuit analysis that may be part of the simulation above.
- iv)* Power, energy, and load flow analysis that may be part of the simulation above.
- v)* Power quality analysis that may be part of the simulation required above.
- vi)* Protection scheme that includes a protective device coordination study that may be part of the simulation above.

### 19.5 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 are to be described in the test plan:

- i)* Model in the Loop (MIL)

Model In the Loop (MIL) testing shall 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 approach 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, shall be considered for deployment of the executable code. Combining the various multi-physics models of connected systems onboard 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 SIL test approach, the model and its virtual (emulated) PLCs are simulated without any physical hardware components. SIL approach 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 for our 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.

### **19.7 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 3/19.5 above as applicable.
- iii)** Functional and failure testing of the integrated systems identified in 4-9-3-A2/11 and 4-9-3-A2/15 of the *Marine Vessel Rules* may be demonstrated by modeling and simulation tests.

## SECTION 4 Equipment and Installation

### 1 Electrical Equipment

#### 1.1 General

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

- i)* In general, 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 applicable provisions of Section 4-9-3 of the *Marine Vessel Rules*.
- iii)* ABS may 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 Appendix 2/11.

#### 1.3 Transformers and Converters (1 February 2022)

Application: Transformers and Converters used in the HEPS (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. 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.

#### 1.5 Shaft Generators (SG)

- 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 Section 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 Vessels 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 onboard yachts
  - Shaft generators are to comply with 4-6-2/3.3 of the *ABS Guide for Building and Classing Yachts*.
  - See also Appendix 2/ Table 1, for shaft generators certification requirements, and Appendix 2/11.

### 3 Hazardous Area Installation

#### 3.1 Hazardous Area Classification and Requirements

The following requirements as per the referenced Guides in Table 1, as applicable, are also to be met.

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

<i>Applicable System</i>	<i>Rule &amp; Guide Reference</i>
Battery System Installation	Paragraph 3/3.3 of <i>Lithium-ion Battery Guide</i>
Supercapacitor Systems Installation	Paragraph 3/3.9 of <i>Supercapacitor Guide</i>
Fuel Cell Power Systems Installation	Subsections 5/3, 5/4 of <i>Fuel Cell Guide</i>

#### 3.3 Installation in Hazardous Areas (1 February 2022)

The following requirements as per the referenced Guides in Table 2, as applicable, are also to be met.

**TABLE 2**  
**Installation in Hazardous Areas**

<i>Applicable System</i>	<i>Rule &amp; Guide Reference</i>
Solar PV Electric Power Generation Systems	Subparagraph 5/11.3.2 of this Guide
Wind Electric Power Generation Systems	Subparagraph 6/11.3.2 of this Guide

## SECTION 5

# Requirements for Solar PV Electric Power Generation Systems

(1 February 2022)

## 1 General

### 1.1 Application

In addition to the requirements of this Guide, this Section includes requirements for provisions that apply to the design, construction, and testing of hybrid 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.

## 3 Plans and Data to be Submitted

- i)* All plans and data as requested by 2/1.3 and 2/1.5 of this Guide, as applicable, are to be submitted
- ii)* Documentation showing sizing and optimization calculations of the hybrid electric power system
- iii)* Arrangement of solar PV system and installation location(s)
- iv)* Structural load analysis report and loads used for structural design of support structure, if applicable
- v)* Detail drawings of the foundation and support structure on which the solar PV system is installed
- vi)* Calculations for the foundation and hull interface structure
- vii)* Vessel stability review
- viii)* Anchoring and mooring equipment specifications, where required
- ix)* Electrical system integration plan of solar PV system with ESS and onboard power supply
- x)* Procedure for temporary removal of solar PV array(s), if applicable. See 5/11.3.3 of this Guide
- xi)* Solar PV system documentation in accordance with Clause 4 of IEC 62446-1, which includes the following:
  - 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 Table 1. Test reports are to be submitted to ABS and are to be available to the attending Surveyor.

**TABLE 1**  
**Components Testing Requirements**

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

- i) Nondestructive testing (NDT) inspection plan 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 of this Guide
- iii) Solar PV system documentation in accordance with Clause 4 of IEC 62446-1 (see 5/3.x) of this Guide) 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 of Section 3 of this Guide, 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

In general, 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 Guide.

## 9.5 Power Distribution System

### 9.5.1 General

In addition to the requirements of Subsection 3/5 of this Guide, 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 Guide 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 1/1.1 and 1/1.3 of Appendix 1 of this Guide, 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

In addition to the requirements of Subsection 3/7 of this Guide, 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 Section 4-9-2 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 of Subsection 3/9 of this Guide, 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 should 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 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 Guide 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 of this Guide, 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) Paragraph 4/1.3 of this Guide
- ii) Subsection 3/11 of the *ABS Guide 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 7/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 5/5 Table 1 of this Guide.

### 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 5/5 Table 1 of this Guide.

### 11.1.7 Warning Labels and Markings

All PV Solar electrical equipment are 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 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 onboard 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 should be in place to ensure 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 Guide for Wind Assisted Propulsion System Installation* as applicable.

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

### 1 General

#### 1.1 Application

In addition to the requirements of this Guide, this Section includes requirements for provisions that apply to the design, construction, and testing of hybrid 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.

### 3 Plans and Data to be Submitted

- i)* All plans and data as requested by 2/1.3 and 2/1.5 of this Guide, as applicable, are to be submitted
- ii)* Documentation showing sizing and optimization calculations of the hybrid electric power system
- iii)* Arrangement of wind turbine generator system and installation location(s)
- iv)* Structural load analysis report and loads used for structural design of support structure
- v)* Detail drawings of the foundation and support structure on which the wind turbine generator is installed
- vi)* Calculations for the foundation and hull interface structure
- vii)* Vessel stability calculation including the effect of wind turbine
- viii)* Anchoring and mooring equipment specifications (Compliance with Circle E 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 ABS Rules for Building and Classing Marine Vessels is equal to or greater than 205)
- ix)* Electrical system integration plan of wind turbine generator system with ESS and onboard power supply
- x)* Manufacturer's design documentation for design class "S" wind turbine. See 6/9.17 of this Guide
- xi)* Procedure for lowering wind turbines on tilt-up towers, if applicable
- xii)* Procedure for temporary removal of wind turbine(s) and/or wind turbine blades, if applicable. See 6/11.3.3 of this Guide
- xiii)* Wind turbine generator system documentation in accordance with Clause 11 of IEC 61400-2, which includes the following:

- 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

## 5 Certification

### 5.1 General

The wind turbine generator system is to be tested and certified in accordance with the following Table 1. 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<sup>(3)</sup>**

<i>Test</i>	<i>Reference</i>
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 <sup>(1)</sup>	IEC 60068-2-52 Test Kb
Vibration test <sup>(2)</sup>	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 shall 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 shall 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

- i) Nondestructive testing (NDT) inspection plan 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 of this Guide
- iv) Wind turbine generator system documentation in accordance with Clause 11 of IEC 61400-2. See 6/3.xii) of this Guide

## 9 System Design

### 9.1 General

In addition to the requirements of Section 3 of this Guide, 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 Guide 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 onboard (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 Guide 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 Guide for Wind Assisted Propulsion System Installation*.

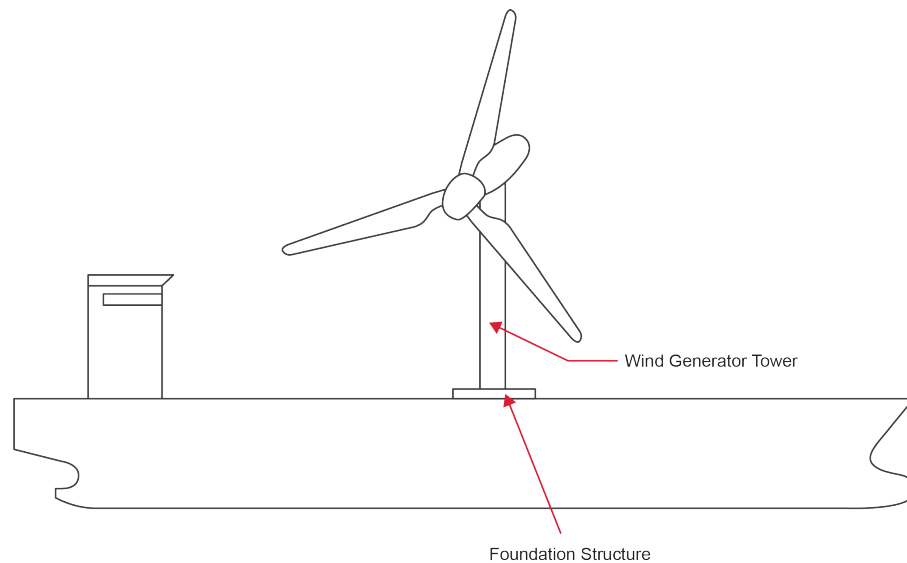
The wind generator tower is outside the scope of class. Refer to Section 6/Figure 1.

#### Notes:

- 1 The support structure for wind turbines of up to 40 m<sup>2</sup> 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 Guide.



**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 of this Guide 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 is to account for the wind effect, windage obstructions onboard, 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 of this Guide, 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 Guide 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 1/1.1 and 1/1.3 of Appendix 1 of this Guide, 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 of this Guide, 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 of this Guide, 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

Small 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 Guide 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 Guide 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 Guide 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 of this Guide, 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 Guide 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 6/5 Table 1 of this Guide.

### 11.3 Installation

#### 11.3.1 General

In addition to the requirements of 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 Subsection 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<sup>2</sup> 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 onboard 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<sup>2</sup> 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 3-6-1 of the *Marine Vessel Rules*. Also, see Subsection 3/4 of the *ABS Guide for Wind Assisted Propulsion System Installation* for additional guidance.

## **1 Surveys During Construction**

### **1.1 General**

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of hybrid electric power systems (HEPS) onboard. 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**

See Section 2/Table 1 and Table 2 of this Guide for certification requirements of HEPS. 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 HEPS 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**

- i)* Equipment in association with control, monitoring and safety systems of the hybrid 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 of this Guide.

### **1.7 Onboard Testing (1 February 2022)**

- i)* General
  - Onboard testing is to verify that functionality has been achieved with all systems in operation.
  - The hybrid 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.
  - 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<sup>(1)</sup> (1 February 2022)**

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

**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, 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, 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 electric power systems are to be tested in accordance with the provisions in 3/7.7 of this Guide.
- 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.

## 1.9 Initial Survey

### 1.9.1 Surveys During Installation (1 February 2022)

- i) 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
- ii) All certified safe systems (as applicable) and instrumentation and control panels are to be verified to be in compliance with approved drawings.
- iii) 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.
- iv) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.
- v) The Commissioning Test Plan is to be followed and verified by the Surveyor
- vi) For Wind and PV Solar structure installations, the NDT Inspection plans are to be available and verified by Surveyor. See Subsection 5/3 (v) & (5.3) & 7 (i), Wind (Subsection 6/3 (v), (5.3), & 7 (i)).
- vii) 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.
- viii) Where applicable for PV Structure installation, random pull/loading tests should be performed to satisfaction of the attending surveyor.
- ix) Confirmation of removal of panels (e.g. PV solar) in emergency situation
- x) Confirmation of lowering wind turbine
- xi) Confirmation of removal of wind turbine blades

### 1.9.2 Surveys During Trials (1 February 2022)

During the initial trials, the HEPS 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 7/1.7 of this Guide.

### 3 Surveys After Construction

#### 3.1 General (1 February 2022)

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

Annual or Special surveys after construction are to be carried out for systems and equipment as referred to in 7/3.3 of below, as applicable.

#### 3.3 Annual Surveys (1 February 2022)

The Hybrid Electric Power System (HEPS) operating and maintenance records are to be examined to identify any issues with the HEPS.

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 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:

- 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
- ix) Confirmation of visibility
- x) Where applicable for wind turbine installation, Rocking Tests should be performed and the results of these tests are to be recorded for reference for subsequent surveys.

The overall HEPS 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.

#### 3.5 Special Surveys (1 February 2022)

- i) In addition to the annual requirements in 3.3 above, trials are to be conducted as referenced in 7/1.9.2. The results of these tests are to be recorded and maintained on board for reference for subsequent surveys.
- ii) Confirmation of removal of panels (e.g. PV solar) in emergency situation
- iii) Confirmation of lowering wind turbine
- iv) Confirmation of removal of wind turbine blades
- v) For wind turbine installations with a slewing ring, Rocking Tests are to be performed and the results of these tests are to be recorded for reference for subsequent surveys.



### 3.7 Surveys for Existing Vessels Obtaining HYBRID IEPS Notation

#### 3.7.1 Initial Survey (*1 February 2022*)

All vessels subjected to modifications and retrofits with hybrid electric power systems as detailed in this Guide are to be examined and tested in accordance with the approved plans and 7/1.1 through 7/1.9 to verify compliance and to the satisfaction of the attending Surveyor.

**Table for Cross References to existing ABS Guides**

**1 General**

**1.1 Battery System Design and Construction (1 February 2022)**

The provisions of this Section apply to vessel battery energy storage systems. The following references in 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 25 kWh. When batteries are being used as the main source of power, the additional requirements set forth in Section 4 of *Lithium-ion Batteries Guide* are to be met.

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

<i>Battery System</i>	<i>Lithium-ion Batteries Guide Reference</i>
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 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**

<i>Supercapacitor System</i>	<i>Supercapacitor Guide Reference</i>
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

<i>Supercapacitor System</i>	<i>Supercapacitor Guide Reference</i>
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 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**

<i>Fuel Cell Power System</i>	<i>Fuel Cell Power System Guide Reference</i>
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

## Hybrid Electric Power Systems Installed Onboard Yachts

### 1 General

#### 1.1 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 Plan and Data to be submitted

- i) All plans and data as requested by 2/1.3 and 2/1.5 of this Guide 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 ABS *Guide for Building and Classing Yachts* are to be submitted.

### 5 Certification

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 ABS *Guide for Building and Classing Yachts*.

See also Section 2/ Table 2 of this Guide.

**TABLE 1**  
**Hybrid Electric Power System Certification for Yacht**

No.	Equipment	d	m	s	t	obs	g	Yacht Guide Reference
1	Propulsion Generators and Motors	X	X	X	X	X		see 4-6-4/3,4-6-4/Table 1, 4-6-5/3.17.5
2	Switchboards (Propulsion, Main and Emergency)	X		X		X		see 4-6-4/7
3	Motor Controllers $\geq$ 100 kW (135 hp)	X		X		X		see 4-6-4/7.17
4	Battery Charging and Discharging Boards for Essential, Emergency or Transitional Source of Power	X		X		X		see 4-6-4/7.19
5	Power Transformers and Converters of Low Voltage					X	X	see 4-6-4/9, 4-6-4/10, 4-6-4/11

No.	Equipment	d	m	s	t	obs	g	Yacht Guide Reference
6	Power Transformers and Converters for High Voltage Systems Exceeding 1 kV	X		X		X		see 4-6-5/1.11.3
7	Circuit Breakers and Fuses	X				X		see 4-6-4/11
8	Certified Safe Equipment	X			X	X		see 4-6-3/9
9	Shaft Generators (motors)	X		X	X	X	X	4-6-2/3.3, 4-1-1/Table 3c, (as appropriate based on rating)
Symbol	Meaning							
d	DESIGN REVIEW – (Design Review Required)							
m	MATERIAL TESTING – (Material Testing is to be witnessed by an ABS Surveyor)							
s	MANUFACTURING SURVEYS – (Product is to be inspected during fabrication by an ABS Surveyor)							
t	TYPE/PROTOTYPE – (Testing conducted on an actual sample or a prototype model is required, as applicable)							
obs	ON BOARD SURVEYS – Operational, hydrostatic non-destructive testing, or other required tests are to be witnessed by an ABS surveyor after installation on board the yacht							
g	MANUFACTURER'S DOCUMENTATION – (Manufacturer should supply documentation to guarantee that the material or the equipment complies with an acceptable Standard, (e.g., Standard tests reports, Ex Certification, etc.)							

## 7 Onboard Documentation

See Subsection 2/5 of this Guide, as applicable.

## 9 System Design

See Section 3 of this Guide, as applicable.

## 11 Electrical Equipment and Installation

- i) In general, see applicable Sections of Part 4 Chapter 6 of the *ABS Guide for Building and Classing Yachts*.
- ii) See also Section 4 of this Guide, 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

See Appendix 2/Table 1 and Section 2/Table 2 of this Guide for certification requirements for Yachts. Survey requirements for equipment components at the manufacturer's facility are summarized in the applicable sections of the *ABS Guide for Building and Classing Yachts*.

- i) The manufacture, testing, inspection, and documentation of the HEPS 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 *ABS Guide for Building and Classing Yachts*, 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 of this Guide, as applicable.
- iii) Simulation testing for verification of the systems/equipment integration may be performed as per 3/19.7 of this Guide.

### 13.1.3 Onboard Testing

- i) General
  - Onboard testing is to verify that functionality has been achieved with all systems in operation.
  - The hybrid 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 *ABS Guide for Building and Classing Yachts*.

- 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 of this Guide.
- 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

#### i) Surveys During Installation

- In general, the equipment is to be installed in accordance with the manufacturer's requirements as per the installation approved plans, and the *ABS Guide for Building and Classing Yachts* as applicable 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 requirements of Section 4-6-2 of the *ABS Guide for Building and Classing Yachts* 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 HEPS 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 Appendix 2/13.1.3 iv) of this Guide.

## 13.3 Surveys After Construction

### 13.3.1 General

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 for systems and equipment as referred to in Appendix 2/13.3.2 of below, as applicable.

### 13.3.2 Annual Surveys

The Hybrid Electric Power System (HEPS) operating and maintenance records are to be examined to identify any issues with the HEPS.

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 HEPS 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

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

### 13.3.4 Surveys for Existing Vessels Obtaining HYBRID IEPS Notation

#### Initial Survey

All Yachts subjected to modifications and retrofits with hybrid electric power systems as detailed in this Guide are to be examined and tested in accordance with the approved plans and Appendix 2/13.1 to verify compliance and to the satisfaction of the attending Surveyor.