GUIDANCE NOTES
GD 06-2020

CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR SURVEY OF DC DISTRIBUTION ELECTRICAL PROPULSION SYSTEMS

2020

Effective from 1 May 2020

Beijing

CONTENTS

Chapter 1 General....1
1.1 General requirements....1
1.2 Definitions....1
1.3 Drawings and documents....2

Chapter 2 System Design....4
2.1 General requirements....4
2.2 System design requirements....4
2.3 Short-circuit protection....6
2.4 Control and monitoring....6
2.5 Failure Mode and Effect Analysis (FMEA)....9

Chapter 3 Electrical Installations....10
3.1 General requirements....10
3.2 Power supply units....10
3.3 DC main switchboards....11
3.4 Semiconductor converters....12
3.5 Propulsion control systems....12

Chapter 4 Test and Verification....13
4.1 General requirements....13
4.2 Test and verification for systems installed for the first time....13
4.3 Mooring and sea trials....13

Chapter 1 General

1.1 General requirements

1.1.1 The Guidelines are applicable to sea-going electrically propelled ships, and:

(1) the public power station onboard the ship serves both as the main power supply for the ship and the power supply for the propulsion system; and

(2) the main busbar of the public power station uses the DC system with rated voltage of 1.5 kV and below.

1.1.2 The Guidelines set forth provisions for the system design, system short-circuit and overload protection, control and monitoring of the DC distribution system as described in 1.1.1, as well as requirements for the inspection of the DC distribution system and related equipment.

1.1.3 In addition to the requirements of the Guidelines, sea-going electrically propelled ships provided with the DC distribution system specified in the Guidelines are to comply with the relevant regulations and CCS rules according to the ship characteristics and navigation areas.

1.1.4 The provisions of the Guidelines are based on the current application of the DC distribution system. Considering the technology is still in the development stage, if the calculation method, evaluation criteria, manufacturing process, inspection and test method required by the Guidelines can provide the corresponding test, theoretical basis, and use experience or effective recognized standards, they can be accepted as alternative and equivalent methods upon CCS agreement.

1.2 Definitions

1.2.1 For the purposes of the Guidelines, the following definitions apply:

(1) *DC distribution system*: a double line insulation power distribution system that connects DC power sources and DC loads and/or connects AC generator and AC loads through power electronics with bus distributed in the form of DC.

(2) *DC bus*: a DC busbar connecting energy sources and loads.

(3) *Energy management system*: a set of devices monitoring DC bus, controlling power supply units and DC bus protection device to ensure safe operation of the system.

(4) *Pumping voltage*: the voltage rise caused by the electrical energy is fed back to the capacitance on the DC side of the converter. The electrical energy is converted from the mechanical energy by the motor, when the motor driven by converter is in the regenerative braking state.

(5) *Solid-state switch*: a contactless switch using power electronic power semiconductor as the current breaker.

(6) *Battery management system*: an electronic device that controls or manages the electrical or thermal performance of a battery system.

(7) *Battery pack*: a set of devices composed of one or more battery modules in series or parallel connection due to voltage or power requirements and connected to the DC bus as an independent power source.

1.3 Drawings and documents

1.3.1 In addition to the requirements of this Section, drawings and documents are to be submitted in accordance with the provisions in the applicable rules for classification of ships, in which "calculation of harmonic distortion of each major node of the electric power system of electrically propelled ships(including the main switchboard, sub-switchboard, etc.)" is only applicable to the AC distribution grid.

1.3.2 When the manufacturer first installs the DC distribution system on a CCS classed ship, the following drawings and documents are to be submitted for approval:

(1) system specifications which are at least to include the system overview, functions of each major component, system protection principle, system control function and description of the external interface of the system;

(2) single line diagram of the DC distribution system;

(3) short-circuit current calculation of the DC distribution system;

(4) selective protection analysis of the distribution system, including DC and AC parts;

(5) verification data of short-circuit current calculation and selective protection analysis of the DC system, to verify the contents of 1.3.2 (3) and (4);

(6) control and monitoring system diagram of the DC distribution system;

(7) failure mode and effect analysis of the DC distribution system;

(8) programs of mooring and sea trials of the DC distribution system.

1.3.3 After the first installation approval, when a DC distribution system of the same type[①] is subsequently installed on a CCS-classed ship, the ship's information for the first installation is to be submitted and the following drawing and documents are to be submitted for approval:

(1) single-wire diagram of the DC distribution system;

(2) short-circuit current calculation of the DC distribution system;

① The same type means that there is no principle change to the system topology, protection principle and control logic.

(3) selective protection analysis of the distribution system, including DC and AC parts;

(4) control and monitoring system diagram of the DC distribution system.

1.3.4 After the first installation approval, when a DC distribution system of the same type is subsequently installed on a CCS-classed ship, the following drawing and documents are to be submitted for information:

(1) the system specification, which is at least to contain the system overview and block diagram, functions of each major component, system protection principle, system control function and description of the external interface of the system.

1.3.5 After the first installation approval, when a DC distribution system of the same type is subsequently installed on a CCS-classed ship, but there is change to individual component, CCS may require additional drawings and documents to be submitted for approval.

1.3.6 A DC distribution system which has already been principle approved by CCS does not need to meet the requirements of 1.3.2, but drawings and documents are to be submitted according to the requirements of 1.3.3 to 1.3.5.

Chapter 2 System Design

2.1 General requirements

2.1.1 A DC distribution system is to be such that:

(1) all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;

(2) the safety of passengers, crew and ship from electrical hazards will be ensured.

2.1.2 In addition to the requirements of this Chapter, electrical propulsion installations are to comply with the requirements of Chapter 15, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships.

2.2 System design requirements

2.2.1 The voltage and frequency fluctuations of the DC distribution system are to meet the following requirements:

(1) the steady-state and transient fluctuations of the DC bus voltage are to meet the requirements of PART FOUR of CCS Rules for Classification of Sea-going Steel Ships, unless all the equipment connected to the DC bus can work normally within the fluctuation amplitude of the system power supply voltage;

(2) when the DC bus supplies power to the ship's AC power grid by the semiconductor converter, the voltage and frequency fluctuations and voltage harmonic components at the output end of the semiconductor converter are to meet the provisions of 1.2.2 and 1.2.3, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships.

2.2.2 The power supply of a public power station may be a power generation device such as an AC synchronous generator, an AC asynchronous generator, a DC generator, or a storage device such as a battery (or an energy-type super capacitor) for storing electricity. A public power station is to meet the following requirements:

(1) it is to be composed of at least two generator sets;

(2) the DC bus is to be composed of two or more sections;

(3) when any section of the DC bus fails, the remaining power supply is to be able to continue to supply power to the equipment necessary for normal propulsion and ship safety, and guarantee the minimum comfortable habitable conditions.

2.2.3 The power capacity of a public power station is to meet the following requirements:

(1) when any set of main power supply unit is shut down, the remaining main power supply is to have sufficient capacity to prevent a significant drop in system voltage and stall of any motor or failure of any other equipment when the maximum load is loaded.

(2) when the maximum load is loaded, the main power supply is to have sufficient capacity or means, so as not to cause the power distribution system voltage drop significantly and cause the power grid failure.

2.2.4 The DC bus is to meet the following requirements:

(1) when the DC bus is restarted, if the charging device must be used, the power supply of the charging device is to be available;

(2) insulation monitoring is to be carried out on the DC bus, and the insulation monitoring system is to be able to give an audible or visual alarm when the insulation resistance is abnormally low.

2.2.5 If the power supply device needs to be connected to the DC bus through a semiconductor converter, each generator set is to be fitted with a separate semiconductor converter (set), and each battery pack is to be fitted with a separate DC/DC converter (set).

2.2.6 Solid-state switches are to meet the following requirements:

(1) appropriate means are to be designed to reduce di/dt and du/dt generated by the conduction and shutdown of semiconductor devices operating in parallel, so as not to cause damage or breakdown of semiconductor devices.

(2) drive pulse signals of semiconductor devices operating in parallel are to be synchronized accurately.

(3) the solid-state switch buffer circuit is to have overvoltage suppression and fast absorption of fault energy functions; special consideration is to be given to the following: when the short-circuit fault is removed, the overvoltage generated by rapid decline in fault current on both ends of the solid-state switch does not cause damage or breakdown of semiconductor devices, and the buffer process is to be completed before reclosing the solid-state switch.

2.2.7 Each power supply branch connected on the DC bus is to have the function of equalizing current or distributing current according to the set value.

2.2.8 The electrical system is to be designed to suppress or consume braking energy, so as to avoid damage to the electrical system or equipment caused by excessive pumping voltage, and the pumping voltage suppression circuit is not to be started when the motor is in normal operation and electric state.

2.2.9 At the end of the pumping voltage suppression circuit, the voltage on the DC side is not to be lowered too much, so as to avoid causing system instability.

2.2.10 Isolating switches or similar means are to be provided on each branch of the electrical system to prevent injuries caused by personnel touching live parts when the equipment is under maintenance.

2.2.11 When the propulsion motor uses permanent magnet motor, appropriate means are to be provided to prevent high voltage generated by energy feedback from endangering the safety of maintenance personnel.

2.3 Short-circuit protection

2.3.1 Short-circuit calculation and selection of short-circuit protection appliances of the AC system in the DC distribution system are to meet the requirements of 2.5.2, 2.5.3 and 2.5.4 in Chapter 2, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships.

2.3.2 The short-circuit calculation of the DC system in the DC distribution system is to include the simulation model, calculation method and calculation results, and the calculation values of the maximum short-circuit current and the minimum short-circuit current are to be submitted.

2.3.3 The short-circuit selective protection of the DC distribution system is to meet the requirements of 2.5.4, Chapter 2, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships. When it is unable to meet the requirements of 2.5.4.1 (1), Chapter 2, PART FOUR of CCS Rules for Classification of Sea-going Steel Ships, the power supply continuity of the distribution system can be realized through the disconnection of the DC bus protection device subject to agreement of CCS.

2.3.4 The DC bus is composed of two or more sections. In case of a short circuit or similar failure of the bus, the busbar protection device is to operate first and ensure that the power supply can be restored to the non-fault side within 45s, and the semiconductor converter connected to the DC bus on the non-fault side will not be blocked due to the significant voltage drop. Solid-state switches are recommended as busbar protection devices. When other types of protection devices are used, documents are to be provided demonstrating that the same selectivity can be achieved under any conditions.

2.3.5 In case of short-circuit fault of AC system, the power supply and semiconductor converter that provide electric energy for the ship's AC switchboard are to be able to provide and withstand sufficient current and maintain the operation of protection devices in the AC system.

2.3.6 In case of fault in the converter, there is to be a separate protection that isolates the faulty circuit without tripping other branch circuits connected to the DC busbar. The protection may be fuses, DC breakers or solid-state switches. Solid-state switches are to be provided with means to provide physical isolation of circuits.

2.4 Control and monitoring

2.4.1 Control and monitoring of the DC distribution system are to be provided based on the system design principle and the functions of each equipment component, so as to ensure the continuity of power supply of the ship's power grid and the reliable operation of the ship's propulsion system.

2.4.2 The distribution system and propulsion system are to be provided with at least the alarms and displays given in Table 2.4.2. These alarms and displays are to be located in the centralized control station of the engine room (in the local station if without the centralized control station). Alarms and displays equivalent to those given in the Table may be accepted subject to agreement of CCS. Alarms for safety actions and group alarms for propulsion generators, motors and semiconductor converters are to be provided in the bridge.

Monitoring and alarm items of DC distribution system and electrical propulsion system

Table 2.4.2

System	Monitoring parameters	Alarm	Display	Auto shut-down	Remarks
Propulsion generator	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	Prime mover automatic shutdown
	Voltage (high/low)	√	√		To read all phases; not applicable to asynchronous generators
	Frequency or revolving speed (high/low)	√	√		For AC propulsion generators only
	Current		√		To read all phases; not applicable to asynchronous generators
	Power		√		
	Stator windings temperature – high	√	√		To read all phases; for generators > 500 kW
	Generator circuit breakers – open/close		√		Applicable to direct connection to the DC bus without semiconductor converter
	Generator running		√		
	Failure of on-line generator	√			
	Generator cooling medium temperature – high	√	√		If applicable
	Failure of generator cooling pump or fan motor	√			If applicable
	Field current		√		
	Interpole windings temperature – high	√	√		For DC generators
Propulsion Motor	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	
	Voltage (high/low)	√	√		To read all phases. For propulsion motor controlled by frequency converter, the output of frequency converter may be taken as an alternative
	Frequency (high/low)	√	√		For AC propulsion motors only. For propulsion motor controlled by frequency converter, the output of frequency converter may be taken as an alternative
	Armature current		√		To read all phases
	Field current		√		For synchronous motors
	Stator windings temperature – high	√	√		To read all phases; for AC motors > 500 kW only
	Motor circuit breakers – open/close		√		Applicable to direct connection to the DC bus without semiconductor converter
	Motor running		√		
	Motor overspeed	√	√	√	For DC propulsion motors
	Failure of on-line motor	√			
	Motor cooling medium temperature – high	√	√		If applicable
	Failure of cooling pump or fan motor	√			If applicable
	Interpole current		√		For DC propulsion motors only

System	Monitoring parameters	Alarm	Display	Auto shut-down	Remarks
Generator/ Propulsion motor/ Semiconductor Converter of Ship's AC power grid	Voltage		√		Measure the output side of the semiconductor converter; frequency measurement of the output side of semiconductor converter of the generator is not needed
	Current		√		
	Frequency		√		
	Overload (high current)	√			Alarm is given before protective device is activated
	Open/close position for distributing switches		√		
	Converter cooling medium temperature – high	√	√		If applicable
	Failure of converter cooling pump or fan motor	√			If applicable
	Inter-phase reactor temperature – high	√	√		When inter-phase reactor is fitted
	Tripping of filter circuit fuse	√			If applicable
DC Main Switchboard	Busbar voltage (high/low)	√	√		Each section
	Busbar power		√		Displaying total and available power
	Combined failure of switchboard cooling system	√			
	Medium leakage of cooling system in switchboard	√			If applicable
	Activation of busbar protection device	√			
	Activation of generator/ load protection device (fuse or DC circuit breaker, etc.)	√			
	Failure of loaded semiconductor converter	√			Except propulsion motor
	Combined failure of energy management system	√			
	Pre-magnetizing failure of the loaded semiconductor converter	√			If applicable
	Pre-charge failure of the busbar	√			Applicable when pre-charging is necessary
Others	Field circuit earth fault	√			May be omitted in circuits of brushless excitation systems and of motors rated less than 500 kW
	Main propulsion circuit earthing fault	√			

2.4.3 A battery management system is to be provided when the battery is used as the power supply of the DC distribution system. The management system of lead-acid batteries is at least to have the monitoring function of the voltage, discharge current, battery temperature and battery resistance. The management system of lithium batteries (including energy-type super capacitors) is to comply with the requirements of the CCS Guidelines for Surveys of Pure Battery-powered Ships.

2.4.4 An energy management system is to be provided to ensure adequate power supply under normal operating conditions of the ship, with at least the following functions:

(1) generator start/stop;

(2) automatic grid-connection and load distribution of the power supply;

(3) automatic disconnection of the power supply;

(4) automatic unloading of non-essential services;

(5) heavy load start request;

(6) reverse power protection, which can be exempted if the semiconductor converter can block any power feedback;

(7) sequence starting of essential services;

(8) data transmission with the battery management system (if any).

2.5 Failure Mode and Effect Analysis (FMEA)

2.5.1 The FMEA required by the Guidelines is to analyse and record each component of the DC distribution system in accordance with the System Reliability Analysis Techniques - Failure Modes and Effect Analysis (FMEA) Procedure published by IEC60812 as a minimum. Each component of the AC distribution system does not need to be included in the FMEA. The FMEA generally includes, but not limited to the following failure analysis:

(1) failure analysis of generator and its semiconductor converter;

(2) failure analysis of energy storage device, such as battery, energy-type super capacitor, management system of battery (or energy-type super capacitor), etc.;

(3) failure analysis of the main components in the DC main switchboard, such as semiconductor converter, solid-state switch for busbar connection, fuse, energy management system device, generator protection device, isolating switch, etc.;

(4) failure analysis of DC main switchboard cooling system;

(5) short-circuit failure analysis of DC main switchboard.

Chapter 3 Electrical Installations

3.1 General requirements

3.1.1 Electrical installations constituting DC distribution systems are to be manufactured and tested in accordance with international or national standards. For new equipment to which there is no applicable standard or for new use of equipment, documents are to be submitted to demonstrate its equivalence to conventional installations.

3.1.2 In addition to the provisions of this Chapter, manufacturing, testing and survey of the electrical installations in the DC distribution electrical propulsion system are to comply with the relevant provisions of CCS Rules for Classification of Sea-going Steel Ships and Guidelines for Survey of Marine Products.

3.2 Power supply units

3.2.1 Generating sets with rated power of 50 kVA or above are to be subject to unit/batch inspection and be furnished with CCS product certificate.

3.2.2 The steady-state short-circuit test specified in Table 6.3 of the Guidelines for Survey of Marine Products E - 04 Generators may be verified according to the following provisions: AC generator and its excitation system in the steady-state short-circuit condition, are at least to be able to maintain its maximum short-circuit current set by their protection device, and the tolerance time is the maximum breaking time set by the protection device.

3.2.3 The type test of three-phase AC asynchronous generators is to be in accordance with Table 3.2.3. After obtaining the type approval certificate, unit/batch inspection items are at least to include items 1 to 8 listed in the Table.

Type Test Items for Three-Phase Asynchronous Generators Table 3.2.3

No.	Test item	Technical requirements
1	Visual examination	Approved plans and technical documents
2	Measurement of insulation resistance	3.2.9.6, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships
3	Measurement of winding resistance	Technical specifications
4	Overload/overcurrent test	3.2.5.1, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships
5	Overspeed test	IEC 60034-1 para. 9.7
6	Withstand voltage test	IEC 60034-1 para. 9.2
7	No load test (measurement of no-load current and no-load losses)	GB/T 19071.2 para.4.5
8	Examination of bearings	3.2.9.16, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships
9	Measurement of maximum torque	GB/T 1032 para.9
10	Measurement of operating characteristic curve	GB/T 19071.2 para.4.7

11	Rated load test and measurement of temperature rise	3.2.3, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships
12	Inclination test	CCS Guidelines for Type Approval Test of Electric and Electronic Products
13	Damp heat test	CCS Guidelines for Type Approval Test of Electric and Electronic Products
14	Salt mist test Ka①	CCS Guidelines for Type Approval Test of Electric and Electronic Products
15	Test of degree of enclosure protection	IEC 60034-5

① The statement “Not suitable for installation on open deck” is to be contained in approval certificates and product certificates for products not subjected to salt mist test.

3.2.4 Generating sets do not need to be subject to the parallel operation test or load bridging test required in the Guidelines for Survey of Marine Products E - 05 Generating Sets.

3.2.5 If it is not feasible for AC asynchronous generators to complete all the test items listed in the Guidelines for Survey of Marine Products E - 05 Generating Sets in the factory, upon agreement of CCS, at least items 5.4 (1) to (8) and (17) in the Guidelines for Survey of Marine Products E - 05 Generating Sets are to be completed in the factory, and the rest of the test items are to be completed during the mooring test.

3.2.6 Manufacturing, testing and inspection of lithium batteries (including energy-type super capacitors) are to comply with the provisions of the Guidelines for Surveys of Pure Battery-powered Ships.

3.3 DC main switchboards

3.3.1 DC main switchboards are to be subject to unit/batch inspection and be furnished with CCS product certificate

3.3.2 DC main switchboard cabinets (including busbar) are to comply with the provisions of IEC 61439-1 "low-voltage switchgear and controlgear assemblies, part 1, general rules" and IEC 61439-2 "low-voltage switchgear and controlgear assemblies, part 2, power switchgear and controlgear assemblies".

3.3.3 DC main switchboards are to complete the following routine tests:

(1) visual examination of structure and wiring, and test of enclosure protection grade if necessary;

(2) examination of clearance and creepage distance;

(3) performance test of the cooling system;

(4) electrical function test, checking the performance of semiconductor converters, instruments, alarms, indicators, displays, etc., and the function test of energy management system is to be carried out as far as possible;

(5) temperature rise test of the busbar. For the same type of products in batch production, temperature rise test may only be conducted on the first product;

(6) withstand voltage test;

(7) measurement of insulation resistance.

3.3.4 Certification requirements for components of DC main switchboards are to be in accordance with Table 3.3.4.

List of Certification Requirements for DC Main Switchboards Table 3.3.4

No.	Product name	Document		Approval mode				Plan approval	Remarks
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Fuse	–	X	–	X4	–	–	X	Applicable to generator branch, loaded branch and ship's AC grid branch
2	Isolating switch	–	X	–	X	–	–	X	
3	Solid-state switch of the busbar for connection	–	X	–	X	–	–	X	
4	Generator protective device	–	X	–	X	–	–	X	
5	Energy management system	–	X	–	X	–	–	X	
6	Electrical meter	–	X	–	X	–	–	X	
7	Insulation monitor	–	X	–	X	–	–	X	
8	Contactor	–	X	–	X	–	–	X	
9	Relay	–	X	–	X4	–	–	X	
10	Wire/cable	–	X	–	–	–	X	X	

Symbols:1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional;

2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval;

3) X4: may be accepted upon special agreement of CCS.

3.4 Semiconductor converters

3.4.1 Over voltage and over current protection are to be provided for each semiconductor converter.

3.4.2 Semiconductor converters with power of 50 kW or above are to be certified in accordance with Appendix 1A, Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships.

3.5 Propulsion control systems

3.5.1 Propulsion control systems are to be certified in accordance with Appendix 1A, Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships and may be type tested in accordance with CCS Guidelines for Survey of Marine Products E - 16 Main engine remote control systems.

3.5.2 Software for propulsion control systems is to comply with the provisions of Section 6, Chapter 2, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships.

Chapter 4 Test and Verification

4.1 General requirements

4.1.1 In addition to the test and verification of the DC distribution system specified in this Chapter, the test and survey of the electrical propulsion and power distribution system of the ship are to meet the requirements of the CCS Rules for Classification of Sea-going Steel Ships.

4.1.2 The first installation of a DC distribution system by a manufacturer on a CCS classed ship is subject to testing and document submitting in accordance with 4.2 and 4.3.

4.1.3 The DC distribution system that has obtained principle approval from CCS does not need to be tested and verified as specified in 4.2 when it is installed on a CCS classed ship for the first time.

4.2 Test and verification for systems installed for the first time

4.2.1 Before the DC distribution system is installed on board, the manufacturer is to conduct the following tests, which are to be witnessed by a CCS surveyor on the site, to verify the reasonability of its system protection:

(1) Test of DC bus fault short circuit. In this case, the protective device of busbar is activated, and the power supply will be restored to the ship's power grid within 45s. The semiconductor converter connected to the DC bus will not be blocked due to the significant voltage drop.

(2) Test of fault short circuit of any panel of the DC main switchboard. In this case, the fault panel protective device is activated and the power supply of other panels is not affected. If the foregoing selective protection cannot be achieved, at least the requirements of 4.2.1(1) are to be complied with. If the above tests cannot be completed due to equipment supporting reasons before installation on board, they are allowed to be carried out in mooring and sea trials.

4.2.2 The DC distribution system manufacturer is to, based on the tests in 4.2.1, submit the documents required in 1.3.2(5) to prove the correctness of its short-circuit current simulation calculation and selective protection analysis. The documents are to include at least the test method, test results and fault current waveform of the test specified in 4.2.1 and the fault current waveform of the test is to be compared with the waveform obtained by simulation calculation.

4.3 Mooring and sea trials

4.3.1 When the power supply device of the DC distribution system is a synchronous generator set, the following items are to be carried out in the mooring test:

(1) starting test of the diesel generator set;

(2) simulated performance test for safety system of the diesel generator set;

(3) load test of the diesel generator set, which is carried out at the highest and lowest speed respectively;

(4) sudden loading and unloading tests, which are carried out at the highest speed;

(5) parallel operation and load bridging tests, which are carried out at the highest and lowest speed respectively. Each generator set is to be loaded to 100% load as far as practicable. If 100% loaded test is not met, the combined parallel load is to be at least equal to the total power of the propulsion motor or the load provided by the DC distribution system to the ship's AC switchboard (whichever is greater), upon agreement of CCS.

4.3.2 When the power supply device of the DC distribution system is an asynchronous generator set and has been tested in the factory according to 3.2.5, items 5.4 (9) to (15) in the Guidelines for Survey of Marine Products E - 05 Generating Sets are to be carried out in addition to the tests specified in 4.3.1 in the mooring test.

4.3.3 In addition to the routine test items, the following test items are to be carried out at the sea trial of the DC distribution system:

(1) if there are two or more generator sets operating in parallel in the power load estimation, the least number of generators operating in parallel is to be selected for the test. One of the generating sets is stopped in this condition to verify the continuity of system power supply. If the rated power of the generating sets is different, the generating set with higher power is to be stopped.

(2) a propulsion motor is stopped in the navigation condition to verify the voltage regulation performance and stability of the system, according to the power load estimation.

4.3.4 If the power supply device contains a battery (or an energy-type super capacitor), and the power load estimation includes the condition when only the battery power is used, the stable power supply capacity of the battery to bear the sudden loading/unloading is to be considered. The following test methods can be used or the test report can be submitted subject to agreement of CCS:

(1) sudden loading and unloading tests are to be carried out during the mooring test. The maximum rated power equipment in the power load estimation is selected as the sudden loading and unloading power;

(2) during the sea trial, the maximum power battery pack (or the maximum power energy-type super capacitor pack) is to be stopped for the test, and a propulsion motor is to be stopped for the test.