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GUIDELINES FOR DYNAMIC POSITIONING SYSTEM BASED ON CLOSED BUSTIE

2024

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Chapter 1 General

Section 1 General Provisions

1.1.1 General Requirements

1.1.1.1 This guideline aims to provide guidance for the design, configuration and verification of power systems with linear and ring-type closed bustie in dynamic positioning systems. For dynamic positioning systems with segmented bustie operation, reference can be made to Chapter 11, Part 8 of the *Rules for Classification of Sea-Going Steel Ships*. This guideline focuses on the technical requirements related to closed bustie.

1.1.1.2 The term "ship" in this guideline refers to ships or offshore facilities equipped with dynamic positioning system.

1.1.1.3 The relevant failure modes and technical means listed in this guideline are based on the existing technical experience and understanding. China Classification Society (hereinafter referred to as "CCS") accepts new technologies and new methods in addition to those listed in this guideline, provided that these new technologies and means equally ensure the integrity, reliability, and safety of system, and have been assessed by CCS.

1.1.1.4 This guideline primarily addresses the power systems of ships or offshore facilities with linear and ring-type closed bustie in dynamic positioning systems, including requirements for power management systems (PMS/EMS). For control systems, peripheral measurement systems, auxiliary systems, and safety systems that have not been specifically addressed, the requirements for open-loop dynamic positioning systems shall be adhered to in addition to meeting fault ride-through requirements.

1.1.1.5 This guideline are specifically for the requirements on power distribution, equipment and system related to the dynamic positioning system. For the feeder circuits of other operating equipment such as drilling and lifting equipment, if a fault occurs and affects the dynamic positioning of the ship, it is necessary to meet the coordinated protection requirements such as short circuit, grounding, and phase imbalance, but there are no rigid requirements for functions such as fault ride-through.

1.1.2 Scope of Application

1.1.2.1 This guideline is applicable to DP-2 and DP-3 systems with switching closure between AC/DC main busties and switchboards, as well as systems with similar configurations/functions to DP-2 and DP-3, such as DP systems with similar configurations/functions, dual power supply systems with similar closed bustie power station configuration /functions, etc.

1.1.2.2 Switch closure between busties of different redundant groups, including linear bustie closure and ring bustie closure, is referred to as closed bustie. Unless specifically stated otherwise, the content in this Guideline applies to power systems with above two types of bustie closures.

1.1.3 Class Notation

1.1.3.1 DP-2/DP-3 systems that meet the requirements of this guideline may be assigned the following class notations:

DP-2 (CBV): For initial survey, it shall pass the shipboard practical test of short circuit and grounding faults (limited to main busties of high-voltage systems). During the special survey on the 5th year, it shall pass shipboard simulation test and meet the relevant testing requirements specified in Chapter 4.

DP-2 (CBNV): It shall pass shipboard simulation test (including short circuit, grounding, and phase imbalance) and meet the relevant testing requirements specified in Chapter 4.

DP-3 (CBV): It shall pass the shipboard practical test for short circuit and grounding faults in initial survey and the 5-year special survey. The relevant testing requirements specified in Chapter 4 shall be satisfied.

DP-3 (CBNV): It shall pass the shipboard practical test for short circuit and grounding faults in initial survey. During the 5-year special survey, it shall pass shipboard simulation test (including short circuit, grounding, and phase imbalance) and meet the relevant testing requirements specified in Chapter 4.

1.1.4 Abbreviations and Definitions

1.1.4.1 The meanings of the English letters appearing in this guideline are as follows.

Abbreviation	Meaning
AVR	Automatic Voltage Regulator
CBV	Closed Bustie Onboard Verification
CBNV	Closed Bustie Not Onboard Verification
DP	Dynamic Positioning
EMS	Energy Management System
FMEA	Failure Mode and Effect Analysis
AGPS	Advanced Generator Protection System
PMS	Power Management System
IMO	International Marine Organization
WCFDI	Worst Case Failure Design Intent
AMS	Alarm and Monitoring System
BMS	Battery Management System
IAS	Integrated automation system

1.1.4.2 The definitions referred to in this guideline are as follows:

(1) Main protection: The protection that meets the requirements for system stability and equipment safety, and can selectively remove faults in protected equipment and lines at the fastest speed.

Linear closed bustie power stations can accept only the main protection set reliably.

(2) Backup protection: The protective equipment or system that works when the protective device closest to the fault point fails or lacks the ability to clear the fault in a timely manner, or when other protective devices fail.

(3) Auxiliary protection: The simple protection added to supplement the performance of main and backup protection or when the main or backup protection is out of operation. Auxiliary protection cannot replace main and backup protections.

(4) Fault ride-through capability: The ability of DP system-related equipment (excluding equipment isolated due to faults) to recover to its pre-fault operating capacity after the fault is automatically cleared, without requiring a restart or manual intervention. The fault ride-through stage generally refers to the stage from the occurrence of the fault to the recovery of the voltage and frequency of the power system to the steady-state value.

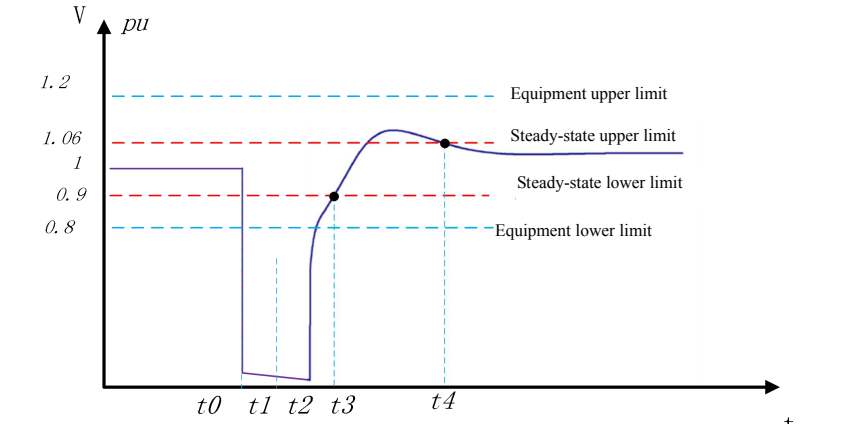

Figure 1.1.4.2 Typical Short-Circuit Ride-Through Process

(5) Quick recovery: The ability of certain redundant groups, including generator sets, switchboards, thruster systems, etc., to automatically restore to an available state within a specified time according to preset logic after losing power due to overload, short circuit, misoperations, etc.

(6) Dual power supply: The form of power supply where busbars of different redundant groups simultaneously supplys power to one or the equivalent busbar. The powered busbar may not be related to the DP system.

(7) Tie switch: The switch (typically including circuit breakers, solid-state switches, disconnectors, etc.) that connects two busties within the same redundant group.

(8) Bus-tie switch: The switch (typically including circuit breakers, solid-state switches, etc.) that connects busties of different redundant groups.

Section 2 Technical Principles

1.2.1 General Requirements

1.2.1.1 The closed bustie DP system shall possess certain stability, reliability, and safety, which shall be reflected before and after the occurrence of faults including hidden failures. Common hidden failures include sensor freeze-up, drift, protective device failures, protective control device malfunctions, communication line failures, and interface failures.

1.2.2 Basic Requirements for Power Stations

1.2.2.1 The voltage, frequency, and other data shall meet the requirements of CCS specifications. Electrical equipment shall be able to operate reliably under the fluctuation of voltage and frequency deviating from the rated value specified in Table 1.2.2.1 (measured at the input end of the equipment):

Voltage and Frequency Fluctuations Table 1.2.2.1

Equipment	Parameter	Steady state (%)	Transient	
			(%)	Recovery time (s)
General AC equipment	Voltage	+6～-10	±20	1.5
	Frequency	±5	±10	5
DC equipment powered by a DC	Voltage	±10	--	--
	Periodic voltage	5	--	--

Equipment		Parameter	Steady state (%)	Transient	
				(%)	Recovery time (s)
generator or via a rectifier		fluctuation			
		Ripple voltage	10	--	--
Equipment powered by batteries:	Connected to batteries during charging①	Voltage	+30～-25	——	——
	Not connected to batteries during charging		+20～-25	——	——

Note: Consideration shall be given to different voltage fluctuations determined by charging/discharging characteristics, including the fluctuating voltage of charging equipment.

1.2.2.2 The harmonic components shall meet the requirements specified in Chapter 1, Part 4 of CCS *Rules for Classification of Sea-going Steel Ships*.

1.2.2.3 Other requirements such as environmental conditions and grounding shall meet the requirements of CCS regulations.

1.2.2.4 System protections such as short-circuit protection, generator protection, motor protection, etc. shall meet the requirements of CCS regulations.

1.2.2.5 The high-voltage switchboard system shall meet the requirements specified in Section 14, Chapter 2, Part 4 of CCS *Rules for Classification of Sea-going Steel Ships*.

1.2.2.6 The DC power distribution system shall meet the relevant requirements specified in CCS *Rules for Classification of Sea-going Steel Ships* and *Guidelines for Survey of Ships Using DC Integrated Power System*.

1.2.2.7 The lithium power battery system shall comply with the relevant requirements of *CCS Rules for Ships Applying Battery as a Power*.

1.2.3 Reliability Requirements

1.2.3.1 The closed bustie system shall possess a certain degree of reliability to ensure system continuity and stability. Specific measures include:

(1) The impact of single failure for the system shall be minimized, with the maximum impact not exceeding WCFDI.

(2) Control circuits, UPS, auxiliary systems, etc., of different redundant groups shall not be crossed as much as possible.

(3) Systems required for overall ship control, such as control/communication networks (including switches, network distribution units), AMS, IAS, PMS, AGPS, and thruster control systems, shall have interfaces that meet certain electrical/physical isolation requirements. Hardware equipment and communication lines shall meet certain redundancy requirements. Through FMEA analysis, there shall be no common failure points exceeding WCFDI.

(4) Additional physical separation, high-reliability equipment/transformers and measurement control devices, appropriately high-grade insulated busties, bus coupler cables with the minimum number of cores, additional protection logic for auxiliary judgment, monitoring of trip coils for main busbar-connected circuit breakers, etc., shall be used.

(5) More/additional auxiliary communication, monitoring, and alarm, indication functions, monitoring of equipment/system status, measurement signals, action execution and results, reverse locking, and other auxiliary measures, as well as protection and management logic judgment of auxiliary systems.

(6) Input signals for main and backup protections shall not come from the same transformer. Verification signals for protection, management, etc., shall not come from the same transformer.

For AGPS, when the transformer is sufficiently reliable, the above requirements can be appropriately relaxed, with the impact of single failure on the power station minimized.

(7) Standby equipment/systems, such as standby pumps, sensors, control circuits, crossover power supplies, etc., shall be equipped with status monitoring or alarm indication functions.

(8) Equipment prone to misoperation shall have corresponding measures to prevent misoperation.

1.2.3.2 Control commands, status signals, communication connections, etc., shall have self-diagnostic functions as much as possible. When inconsistencies occur, timely alarms shall be given to prevent misoperation.

1.2.3.3 Control components (including various instruments, relays, transformers/sensors, coils, monitoring circuits) shall be able to withstand vibrations and fault ride-through caused by switching on and off without misoperation.

1.2.3.4 The main circuit breakers and feeder circuit breakers of the generator connected to the main bustie shall use double tripping coils (excluding bus coupler breakers) as much as possible. If the above circuit breakers use a single tripping coil, they shall be equipped with monitoring circuits, or other measures such as circuit breaker fault protection (such as 50BF) are also acceptable. The bus coupler breakers of DC power stations shall also consider hidden failures.

1.2.4 Safety Requirements

1.2.4.1 Any closed bustie DP system shall be able to operate normally with the bus coupler disconnected.

1.2.4.2 Key equipment and systems such as generators, thrusters, and PMS shall have measures to prevent misoperation, including equipment start/stop, switch closure/opening, interlocking operations, synchronization operations, etc.

1.2.4.3 Lithium power batteries serving different redundant groups and those operating in parallel with diesel generator sets within the same redundant group shall be arranged in separate compartments. The layout and monitoring, ventilation, fire protection, and other systems in these compartments shall meet DP redundancy requirements and the relevant requirements of the CCS *Rules for Ships Applying Battery as a Power*, with minimum power alarms and indications provided to meet the quick recovery and standby power requirements of the closed bustie power station.

1.2.4.4 In DP mode, the number of busbars losing power in the closed bustie power station shall not exceed WCFDI.

1.2.4.5 The simulation results and test results of all protections in the closed bustie power station system shall be repeatable.

1.2.5 Other Requirements

1.2.5.1 The protection principles for the closed bustie DP are shown in Figure 1.2.5.1 below. Within the same redundant group, Zone C is usually set as the joint for zone protection, while A, B, and D are equipment/feeder protections, and the protection between them shall be selective.

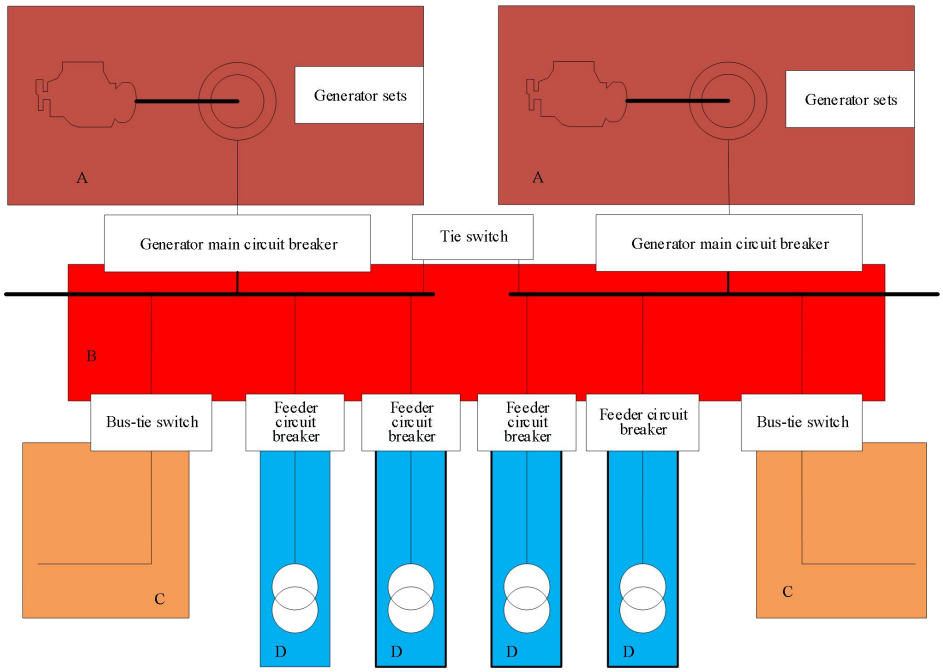

Figure 1.2.5.1 Zone Protection Principles

Section 3 Plans and Documents

1.3.1 General Requirements

1.3.1.1 Drawings and documents related to equipment and systems related to the closed bustie DP shall be submitted for review, and their contents shall meet the relevant requirements specified in Chapter 2 of this guideline.

1.3.1.2 In addition to drawings and documents required by Chapter 11, Part 8 of *Rules for Classification of Sea-Going Steel Ships*, the following information specifically related to the closed bustie DP system shall also be submitted for approval:

(1) Power System and Control, which shall include:

① Introduction to the power system;

The configuration of the power system, definition of DP conditions, power supply scope, relevant interlocks, status of bus-tie switches, WCFDI and others shall be covered.

② Description of grounding methods and selection of grounding resistors;

For high-voltage systems, grounding methods, determination of grounding fault currents, and grounding resistor calculation processes shall be described.

For low-voltage/DC systems, the descriptions of insulation monitoring and its reliability shall be included.

③ Protection settings and operating modes after actuation;

The principles of various protection settings shall be explained, including at least the operating modes after faults in generator set (power supply) incoming lines, feeders, busties, and bus couplers.

④ Generator set and control schematic diagrams and explanations;

The generator protection, dynamic characteristics of generator sets, power management functions, etc. shall be included.

⑤ Operating modes, protection schematic diagrams and explanations for thrusters, switchboards, and transformers/frequency converters;

⑥ Quick recovery;

Include descriptions and logical explanations of automatic restoration processes for generator sets, thruster groups, PMS, etc.

⑦ Power limitation and prevention of localized power loss;

Descriptions and logical explanations of specific power management schemes shall be included.

(2) Functional design of switchboards (including auxiliary switchboards), which shall include:

① Schematic diagrams and explanations of self-control and protection;

②Schematic diagrams and explanations of protection related to closed bustie;

③Schematic diagrams and explanations of generator control and protection;

④ Motor starters (if any);

⑤ Frequency converters;

⑥ Synchronization device principles and explanations;

⑦ External communication and power supply principles and explanations for PMS, AGPS, DP, etc.

(3) Generator set protection system, which shall include:

① Protection principles;

② System composition and power supply;

③ Signal acquisition and communication;

④ Introduction to protection functions;

⑤ Voltage regulator control and monitoring;

⑥ Governor control and monitoring.

(4) Selective protection analysis report, which shall include:

① Description of protection functions;

② Detailed descriptions and settings of each protection function.

(5) Fault ride-through capability analysis, which shall include:

Descriptions of ride-through scenarios and processes, parameter settings, and ride-through time explanations; as well as descriptions of ride-through capabilities for propulsion frequency converters, frequency converters of the steering engine (if any), daily use transformers, thruster transformers, auxiliary systems for thruster motors, circulating oil pumps, steering engines, and other equipment (see 2.8.2.3).

(6) FMEA report (including the final version);

(7) FMEA test verification procedure/report (including test content from Chapter 4);

(8) Communication/control network of closed bustie power station;

(9) Other drawings and documents required based on actual circumstances.

1.3.1.3 The following information shall also be submitted for reference:

(1) Dynamic analysis reports under short-circuit, grounding (for high-voltage systems), and phase imbalance faults, which shall include:

① Working condition description;

② Summary and explanations of parameter settings;

③ Analysis results and explanations;

④ Comparison with the results after the actual ship test (only for comparison with the shipboard practical test results).

(2) Test result record sheets from Chapter 4;

(3) Potential hazard identification analysis reports/explanatory documents before relevant tests of closed bustie power station;

(4) Capacitive current calculation sheets (applicable to high-voltage grounding system);

(5) Other drawings and documents required based on actual circumstances.

1.3.1.4 For DC power stations, in addition to providing the above-mentioned applicable drawings and documents, the following materials shall also be submitted for approval or record-keeping:

(1) Setting and protection instructions of inverters (including various inverters used) (including self-temperature, overcurrent, overvoltage, and undervoltage protection);

(2) Instructions of the power station management system EMS (including BMS);

(3) Coordinated protection analysis and setting of DC power station (including AC components);

(4) Short-circuit current analysis report;

(5) Dynamic analysis report (including ride-through capability analysis) (if required).

Chapter 2 Design Requirements

Section 1 General Provisions

2.1.1 General Requirements

2.1.1.1 When the bustie is closed, the consequences of any single fault shall not exceed the design intent of worst case failure, shall be included in the FMEA analysis and verified by tests. Refer to Chapter 4 for testing requirements.

2.1.1.2 Common protection types and their use are shown in Appendix A. This table can be revised as technology develops.

Section 2 Short-Circuit Current Calculation and Short-Circuit Selective Protection

2.2.1 General Requirements

2.2.1.1 Closed bustie distribution system requires an accurate short-circuit current analysis and calculation. The determination of short-circuit points shall take into account all possible situations, including at least the generator outlet, bustie, low-voltage side of load transformer, and incoming lines of low-voltage switchboards. The short-circuit current calculation shall include the maximum and minimum short-circuit current calculation of three-phase symmetrical short circuit and phase-to-phase asymmetrical short circuit.

2.2.1.2 The mathematical model for short-circuit current calculation shall be accurate enough to provide reference for the selection of switchboards and protective circuit breakers.

2.2.1.3 The design of power system protection shall be selective, particularly for generator incoming switches, load supply switches, bus coupler, transformer high/low-voltage side switches, incoming switches of low-voltage switchboards, and power supply switches for operational equipment. At the same time, the impact of impact current during heavy load startup on selective protection shall also be considered.

2.2.1.4 For high-voltage high-impedance grounding systems, the capacitive current calculation sheet during normal operation shall be submitted.

2.2.1.5 For high-voltage systems with high-resistance grounding or insulation to the ground, the overvoltage caused by intermittent grounding shall not exceed the power frequency test voltage value of any control device and distribution component. If it exceeds the power frequency test voltage, overvoltage suppression measures or equivalent measures shall be provided.

Section 3 Generator Sets

2.3.1 General Requirements

2.3.1.1 Generators shall be equipped with at least the following protections: overload, short-circuit, undervoltage/overvoltage, underfrequency/overfrequency, differential (for generators with a rated capacity of 1500KVA or above), reverse power, and phase imbalance. Temperature monitoring and protection shall be performed on generator stator windings, rotor bearings, and internal circulating air.

2.3.2 Technical Requirements

2.3.2.1 When the bustie DP is closed, generator sets are preferably operated in droop mode. If the generator operates in constant frequency mode, it shall be able to automatically switch to droop mode when faults such as communication or standalone issues occur in the speed control system. The operating mode and switching of generator sets shall not affect the function of AGPS.

2.3.2.2 If the power supply of the generator set management system and governor depends on an external power supply, its power supply shall be as reliable as possible. For DP-3 systems, dual power supply shall be provided whenever possible, with at least one of which shall be UPS, and

cross-feeding between different redundant groups shall be avoided.

2.3.2.3 The operating power supply and control power supply of the automatic voltage regulator (AVR) of the generator shall be independent of other redundant groups, and the power supply shall be equipped with short-circuit protection and monitoring. For DP-3 systems, the control power supply for the automatic voltage regulator (AVR) shall be dual-powered and the power supply shall be equipped with short-circuit protection and monitoring.

2.3.2.4 The generator voltage regulator, diesel engine governor and their own auxiliary systems shall have sufficiently fast response speed and logical response to meet the requirements of rapid startup, sudden loading and unloading, etc.

2.3.2.5 The governors and voltage regulator shall be equipped with status monitoring and feedback signal functions.

2.3.2.6 When the generator set shuts down due to a serious fault, it shall automatically de-excite.

2.3.2.7 Reasonable protection logic shall be set to ensure that the most serious consequence caused by the fault of the generator set does not exceed the maximum WCFDI.

2.3.2.8 When the power distribution form of the main generator sets with different rated powers are connected in parallel on the main busbar of the closed bustie, the matching of their rotational inertia shall be considered during unit selection to achieve speed regulation, voltage regulation performance, and load distribution matching. These shall be included and described in the dynamic analysis report.

2.3.2.9 If power lithium batteries are used as power sources, the protection to be set on the AC side of the power output shall refer to *Guidelines for Survey of Ships Using DC Integrated Power System* .

2.3.2.10 If the power station uses DC generators as power sources, the protection to be set on the power supply side shall refer to the requirements of Chapter 2, Part 4 of *Rules for Classification of Sea-Going Steel Ships* and *Guidelines for Survey of Ships Using DC Integrated Power System* .

Section 4 Switchboard and Power Management System

2.4.1 General Requirements

2.4.1.1 The bustie connected to the generator shall be equipped with protections such as short circuit, grounding, negative sequence, undervoltage/overvoltage, underfrequency/overfrequency, etc.

2.4.1.2 The failure modes of the switchboard shall at least include short circuit, grounding, phase imbalance, underfrequency/overfrequency, grid fluctuations caused by sudden loading and unloading, and failures of circuit breakers, transformers, protection relays, and communication networks.

2.4.1.3 The configuration and composition of the power management system shall be coordinated with the configuration and composition of the AGPS system.

2.4.2 Technical Requirements

2.4.2.1 For DP-2/3, the connection of the main bustie between different redundant groups shall consist of two circuit breakers, and appropriate interlocking shall be provided between the circuit breakers. Each circuit breaker shall be controlled by a different protection relay.

2.4.2.2 The tie switch between busties in the same redundant group can be a circuit breaker without monitoring the circuit and without participating in the selective protection, provided that the voltage will not exceed WCFDI after failure.

2.4.2.3 For the transformers of thrusters and operating equipment powered by the bustie, if they have pre-excitation function, the primary voltage of the transformer shall be same as that of the power grid when the switch is closed, so as to avoid the impact of the closing process on the

power grid and other equipments.

2.4.2.4 When the bustie DP is closed, the automatic paralleling operation of the generator shall be subject to at least two detection functions to prevent false synchronization.

2.4.2.5 The switchboard shall have the highest possible reliability and integrity, such as using the insulated busbars for high-voltage switchboards, enduring the maximum short-circuit current as long as possible, and employing clean gas or vacuum circuit breakers for air/clean gas-insulated cabinets and circuit breakers. Low-voltage switchboards and DC switchboards shall be equipped with insulation monitoring which shall be able to work reliably under open and closed conditions.

2.4.2.6 When the bustie is closed, the power management system shall communicate with the AGPS to achieve:

(1) Isolation of the faulty generator set and start-up of the standby generator;

(2) Confirmation of the local power failure state and start of the rapid recovery operation;

(3) Realization of the safe switching of the power station load distribution mode and other functions.

2.4.2.7 For DP-2/3 systems, restarted generators, generator sets that have been started but not paralleled, and unconnected battery sets shall not be used as hot backup power supplies.

2.4.2.8 In DP mode, under linear closed bustie, the number and distribution of online generators allowed shall be considered in combination with WCFDI, online generator load rate principles, possible short circuit/ground failure modes, etc. Under closed bustie, if the minimum number of generators allowed by the power station (including battery sets) is 2, the two online generators shall run on busties of different redundant groups.

2.4.2.9 Under closed bustie, the load rate of a single online generator shall not exceed (N-1)/N, where N is the total number of online generators. If the generator sets on the same bustie share fuel supply pumps, fresh water cooling pumps, etc., and the pumps are not automatically backed up, the generator sets on the same bustie shall be taken as a single unit. This principle also applies to other power supply equipment such as battery packs.

2.4.2.10 The thrusters that need to be switched or restarted shall not be involved in the DP result analysis and calculation.

2.4.2.11 When the power distribution form of the main generator sets with different rated powers are connected in parallel on the main busbar of the closed bustie, the influence of different rotational inertia and different governors/voltage regulators on the stability of the power station shall be considered during the selection and matching. The simulation calculation results shall be submitted to prove that the influence of the governors/voltage regulator can meet the PMS load distribution requirements during sudden loading and unloading, will not trigger the isolation of the healthy machines by AGPS, will not cause load alternation transfer, and that the instantaneous reverse power shall not affect the operation of the generator set and the safety of the power station.

Section 5 Advanced Generator Protection System (AGPS)

2.5.1 General Requirements

2.5.1.1 For AC systems, the advanced generator protection system refers to the protection that is different from conventional reverse power, undervoltage, short circuit, grounding, etc., and is specifically used to monitor and protect the dynamic performance parameters of the generator set such as voltage, frequency, excitation, speed, active/reactive power, etc.

2.5.1.2 For adjustable speed diesel generator sets in DC power stations, in addition to the protection required by relevant specifications, AGPS may not be set up additionally, but the power station shall be equipped with a reliable protection function to cut off faulty generators and busties.

2.5.2 Technical Requirements

2.5.2.1 AGPS shall be able to detect the internal input dynamic parameters of the engines and generators, the output measurement values and the set parameters in real time, and compare them to timely identify the faulty generator set and take measures. An example of the AGPS working mode is shown in Figure 2.5.2.1 below.

In the figure below, the box represents the protection setting range of AGPS, and the slash represents the load distribution curve set in PMS. Whether it is overfrequency/underfrequency caused by overfuel/underfuel, as long as the F-P point is within the AGPS box, AGPS considers it a healthy machine. If it deviates from the box, AGPS considers it a faulty machine and isolates it. AGPS can also implement protection based on the P-Q diagram (active/reactive power curve).

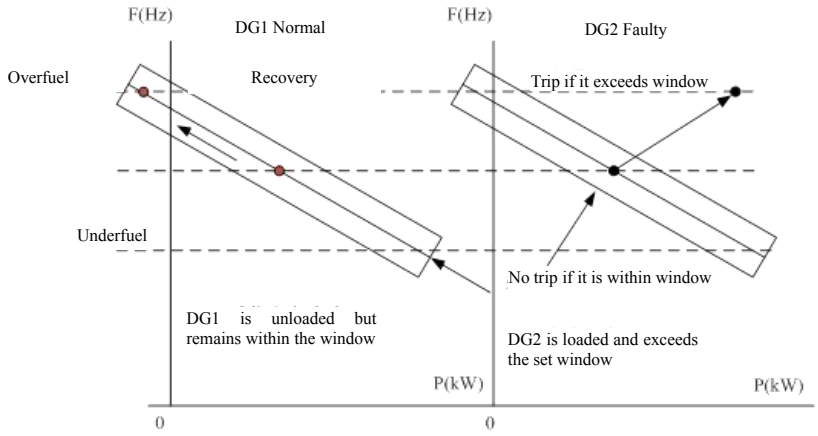

Figure 2.5.2.1 Generator Protection Mode

2.5.2.2 The AGPS report submitted shall describe the functions of AGPS, power supply, logical control, and basic performance of the generator set, such as voltage regulation and speed regulation characteristics, as well as settings for generator and zone protection. The setting shall include the judgment of overvoltage/undervoltage, overexcitation/underexcitation, overfuel/underfuel, over-frequency/under-frequency, reactive/active power distribution, reverse power, etc. of the generator set protected by AGPS.

2.5.2.3 Under the closed bustie, the AGPS systems of the generators in different redundant groups shall be independent of each other. The independence here refers to the protection function, communication, and power supply. In DP-2, each redundant group shall be equipped with at least one set of AGPS, and the controller in the AGPS shall be equipped with hot backup. In DP-3, each redundant group shall be equipped with at least two sets of AGPS, and the controllers, communication lines, power supply circuits, excitation signals, and rack position signals of the two sets of AGPS shall be independent of each other (except for power supply and transformer).

2.5.2.4 For closed bustie power stations, the ability of the AGPS system to identify faulty generators shall match the minimum number of online generators designed for the system, and the identification method/principle shall be clearly stated in the documents submitted for review.

2.5.2.5 AGPS is based on the performance/functions of diesel engines/governors and generators/voltage regulators for protection. Coordination protection analysis is generally provided by the power station contractor. The shipyard or design institute shall coordinate all parties and provide coordination documents for AGPS protection and power system protection for approval.

2.5.2.6 For DC closed busbar power stations, the protection analysis of the DC power station and the AC power station shall be submitted in the same report for review.

2.5.2.7 AGPS shall be independent of ship automation, AVR, speed control system and sub-units involved in active and reactive power distribution. When AGPS can be turned off, there shall be at least the main and backup protection measures for the generator, and actual onboard verification is

required.

2.5.2.8 When AGPS is lost due to power failure, misoperation, etc., it shall not affect the operation of all online healthy generators, and shall provide an alarm and display indicating the AGPS loss/failure in attended locations.

2.5.2.9 When the AGPS on a bustie section is lost, the remaining AGPS in the power station shall still have the capability to isolate the bustie with the faulty generator sets after the generator sets on that bustie section fail.

2.5.2.10 AGPS shall be able to monitor the excitation current and output voltage of the automatic voltage regulator. If the deviation exceeds the preset value, the isolation action shall be implemented immediately.

2.5.2.11 The generator protection system shall be able to compare the actual opening position of the engine throttle (if any) with the actual output power. If the deviation exceeds the preset value, the isolation action shall be implemented immediately.

Section 6 Protection Settings for Closed Bustie Power Stations

2.6.1 Requirements for AC Power Stations

2.6.1.1 The total consequence of a single failure in the power station and a hidden failure of the bus-tie switch or protection relay shall not exceed WCFDI.

2.6.1.2 Hidden failures of the tie switch in the bustie can be ignored if they do not exceed the worst case failure design intent.

2.6.1.3 Protection shall be fail-safe. Failure of a single component shall not affect the function and execution of the main and backup protection at the same time.

2.6.1.4 The main and backup protection for the same system/equipment shall be based on different relays. If the monitoring and measurement signals come from the same transformer/sensor, they shall come from different coils of the same transformer/sensor. The triggering of the main and backup protection functions shall come from different controllers or relays, and the tripping signals shall be sent to different circuit breakers.

2.6.1.5 The power supply of controllers and relays related to busties of different redundant groups shall be independent of each other and cannot be cross-fed.

2.6.1.6 Auxiliary protection can use the same signal source as the main or backup protection. Auxiliary protection shall not affect the main and backup protection. For example, the failure of the reverse blocking function cannot affect the backup protection function.

2.6.1.7 For DP-3 system, the transformer/sensor shall be equipped with necessary monitoring or measurement means. When the monitoring or measurement fails, relevant functions shall be shielded to prevent the original logical actions from occurring, provided the fail-safe principle is met, and an alarm shall be triggered promptly.

2.6.1.8 The communication circuits of the relays, controllers, and signal transmission related to the protection of closed bustie power station shall be sufficiently reliable, and the result of single failure (such as switch/router failure, disconnection, short circuit, grounding, etc.) shall not exceed WCFDI. The communication rate shall match the expected selective protection scheme.

2.6.1.9 The action sequence of the selective protection system of the closed bustie power stations shall be reasonable. Under the premise of not exceeding the DP's most severe design fault intent, the isolation shall be as small as possible in terms of area and as rapid as possible in terms of speed.

2.6.1.10 For the selective protection of the closed bustie power station, a single signal failure (including transformer and communication circuit failures) shall not exceed WCFDI.

2.6.1.11 In the selective protection, it shall be able to identify and distinguish the large current

instantaneously flowing through the bus coupler due to load distribution and the zero current flowing through the bus coupler due to load balancing without causing false operation, which can be judged with the help of auxiliary signals.

2.6.1.12 For the closed bustie power station, different types of selective protection shall meet the coordination. Short-circuit protection shall not trigger grounding protection, and grounding protection shall not trigger phase imbalance protection. These protections and coordination shall be analyzed in FMEA and verified in the test.

2.6.1.13 The AGPS, AVR, and relays shall be coordinated for undervoltage/overvoltage and underfrequency/overfrequency protection of the power station (AVR if any). These protections and coordination shall be analyzed in FMEA and verified in the test.

2.6.1.14 Selective protection shall at least consider the following failure protections, and at least one reliable protection shall be set for each failure. For undervoltage/overvoltage and underfrequency/overfrequency protection, when the system protection selectivity is set, it is also necessary to consider the coordination with the protection/allowable value set by the equipment manufacturer itself. For DC systems, the inverter's own overcurrent setting value and the role of overvoltage protection shall also be considered.

(1) Short circuit;

(2) Grounding;

(3) Phase imbalance;

(4) Sudden loading and unloading.

2.6.2 Requirements for DC Power Stations

2.6.2.1 For DC power stations, the hidden failures of the bus coupler breaker between the main bus ties shall be considered, such as controller failure of the solid-state switch. For DP-3 system, two bus coupler breakers between the main busties shall be set.

2.6.2.2 The protection settings of DC power stations shall refer to the relevant requirements of CCS *Rules for Classification of Sea-going Steel Ships* and *Guidelines for Survey of Ships Using DC Integrated Power System* .

Section 7 Quick Recovery

2.7.1 General Requirements

2.7.1.1 Different detection signals shall be provided to confirm the occurrence of power failure of the main bustie, and the power management system, switchboard, generator set and propulsion system shall implement rapid start-up according to the logic program preset by the PMS.

2.7.1.2 The quick recovery capability mainly depends on the configuration and performance of the generator set, the configuration of the thruster and the PMS logic setting. At the initial design stage, the corresponding quick recovery capability requirements of the generator set, thruster and PMS shall be clearly defined.

2.7.1.3 The generator set, thruster and its auxiliary systems shall have a certain degree of autonomy, such as the use of engine-driven lubricating oil pumps, cooling pumps, fuel pneumatic pumps, etc., to facilitate rapid start-up and power restoration. During the rapid recovery process, different recovery time and sequences can be set according to the importance of the auxiliary systems, but they must be conducive to the quick recovery of the system.

2.7.1.4 During the quick recovery, if the main bustie fault is not eliminated, the startup of quick recovery program of the failure section bustie shall be prevented.

2.7.1.5 When a single main bustie loses power, the ability to quickly start and restore power supply shall be determined based on the nature of the failure. The entire recovery time from the PMS quick recovery command to the thruster being ready and connected to the DP control system

shall be completed within 60 seconds. On the main bustie equipped with the main generator set/power supply unit, at least one power supply unit shall be connected to the power supply.

2.7.1.6 When the following failures cause power loss in partial system, the system shall also be able to quickly restore power supply after the failures are automatically cleared:

(1) Failures causing the generator shutdown;

(2) Failure causing the generator shutdown;

(3) ESD resetting after misoperation/malfunction (if feasible).

2.7.1.7 Emergency generators shall not be used as auxiliary power supply during the quick recovery process. During the quick recovery process, no human intervention is allowed.

Section 8 Fault Ride-Through

2.8.1 General Requirements

2.8.1.1 All DP-related control systems (including peripheral equipment), power systems of various voltage levels, thruster systems, UPS and all related auxiliary systems shall have fault ride-through capabilities. The faults here generally refer to the faults listed in 2.8.2.2. The definition of fault ride-through capability is shown in 1.1.4.2.

2.8.1.2 The short-circuit and grounding dynamic analysis reports shall be combined to clearly define the time period of fault ride-through, which shall match the time difference with the coordinated protection action.

2.8.1.3 During the fault ride-through stage, no human intervention or mechanical action shall be taken. After the fault ride-through, the equipment/system shall be able to automatically restore to the state before the fault.

2.8.1.4 For DC power stations, if the bus coupler breaker between the main busties is a solid-state switch that meets the requirements of 2.6.1.2, the ride-through capability of the equipment on the non-fault bustie section can be ignored.

2.8.2 Specific Requirements

2.8.2.1 During the fault ride-through process, different ride-through time can be set according to the importance of the auxiliary system. The ride-through time of the DP control system, thruster system, generator system, and auxiliary equipment shall meet the overall protection requirements.

2.8.2.2 Faults that need to be considered for fault ride-through include:

(1) Voltage/frequency fluctuation range that does not meet the specification requirements caused by sudden load changes;

(2) Bustie short circuit;

(3) Bustie grounding.

2.8.2.3 The equipment/systems recommended to have fault ride-through capability include:

(1) Engine room ventilation fans and dampers;

(2) Main diesel engine-driven control box;

(3) Fuel supply pump and low-temperature fresh water cooling pump of generator set;

(4) Governor and voltage regulator;

(5) Seawater and fresh water cooling pumps and pressure switches for generator set and thruster;

(6) Lubricating oil pumps at the drive end and non-drive end of generator set;

(7) Local control stations of thrusters and key interface boards/boxes/cabinets;

(8) Inverters of thrusters, inverter cooling pumps/fans, cooling pumps/fans of propulsion transformers, and cooling pumps/fans of propulsion motors;

(9) Steering control inverters, steering motors, and lubricating oil circulation pumps of thrusters;

(10) Cooling pumps/fans for daily transformers;

(11) PMS, AMS (if necessary), IAS and its workstation power supply;

(12) Control circuits of high and low voltage switchboard/DC switchboard;

(13) Circuit breakers of generator sets, thrusters, and daily (primary and secondary) transformers;

(14) Circuit breakers between high and low voltage switchboards;

(15) Temperature control valves related to cooling of generator sets and thrusters;

(16) DP control system, peripheral sensors, position reference system, etc.;

(17) AGPS system;

(18) Networks, switches, etc. related to AGPS, PMS, DP, AMS, IAS, etc.;

(19) Inverters for engine room fans, generators, thrusters as well as auxiliary systems (if any);

(20) It shall be analyzed by FMEA and verified by shipboard test whether other equipment needs to have ride-through capability.

2.8.2.4 When main generator sets with different rated powers are connected in parallel to the main busbar of closed bustie, the units shall not be disconnected during the ride-through process.

2.8.2.5 Auxiliary measures for fault ride-through shall be provided, such as real-time monitoring of UPS to prevent the hidden failures.

2.8.2.6 The fault ride-through capability shall be verified on board during the shipboard test.

2.8.2.7 For battery packs, when the main bustie is short-circuited, the BMS shall be able to quickly switch to the discharge mode to provide support for the short-circuit current, and achieve ride-through.

Section 9 Harmonics

2.9.1 General Requirements

2.9.1.1 Harmonics of power stations shall not exceed the requirements of CCS specifications when the busbar is closed or in segmented operation.

2.9.1.2 After the failure of equipment that may affect the harmonics of the power station, if the harmonics exceed the requirements of CCS specifications, countermeasures shall be taken to ensure that the harmonics meet the requirements of CCS specifications.

2.9.1.3 The harmonics of the power station shall also meet the requirements of 15.2.2, Chapter 15, Part 8 of CCS *Rules for Classification of Sea-going Steel Ships*.

2.9.1.4 For DC power stations, the harmonics of the AC part shall also meet the above requirements.

Section 10 Dynamic Analysis

2.10.1 General Requirements

2.10.1.1 For closed bustie power stations, according to the actual situation of the ship, a mathematical model shall be established to simulate the operation of the system under normal conditions and the following fault conditions, and the entire calculation process shall be recorded. The simulation analysis shall include the response process of the main and backup protection.

(1) Simulation of short circuit and current at each short-circuit point;

(2) Simulation of impact current when closing the transformer without pre-excitation;

(3) Synchronization of generators on normal buses and protective actions during short-circuit fault clearing process, as well as bustie voltage/frequency recovery processes after typical sudden loading and unloading;

(4) Simulation of phase imbalance faults;

(5) Simulation of excitation and governor failures;

(6) Simulation of grounding faults;

(7) If the power distribution form involves parallel connection of main generator sets with different rated powers on the closed bustie main busbars, the active and reactive power variation curves shall also be included;

(8) Simulation of short circuit and grounding faults of the public switchboard when dual power supply is used.

2.10.1.2 A dynamic analysis report and response parameter sheet shall be generated as the basis for protection setting and shall be consistent with the results of shipboard test.

2.10.1.3 The output parameters in the dynamic analysis report shall be consistent with the parameters of the actual ship.

2.10.1.4 In the mathematical model, the parameter curve of the generator shall be the measured full voltage short-circuit attenuation curve obtained with AVR.

2.10.1.5 If the additional class notation requires shipboard practical test, when the measured results in the shipboard test are inconsistent with the dynamic simulation analysis report, an analysis shall be conducted to identify the reasons, provide explanations, and correct the mathematical model. Once the dynamic simulation analysis report aligns closely or consistently with the measured results, a new report shall be generated and submitted for review.

2.10.1.6 The dynamic analysis shall include all DP distribution modes and typical failure modes to lay the foundation for test verification.

2.10.1.7 The curve of the dynamic analysis shall be continuous and smooth, and the time step shall be selected appropriately. The curve graph shall clearly show the key points such as the start of the fault, protection actions, maximum and minimum values, and the fluctuation of the recovery process. Reasonable explanations shall be given for the curve's changes and fluctuations. During the system's stable phase, there shall be no fluctuations in the curves.

2.10.1.8 In the dynamic analysis curve, the change curves of diesel generator sets of the same model on the non-faulty buses shall be consistent.

2.10.1.9 The generator sets and protection systems in the calculation model shall be consistent with the physical characteristics of the actual equipment, such as the electromagnetic characteristics of the equipment, the logic and sampling links of the generator protection system, etc. The dynamic computer model used to simulate the system under different fault conditions shall be submitted and used to verify the waveforms to ensure sufficient accuracy and resolution, and can be used to demonstrate predictable performance with adequate margins.

2.10.1.10 To verify the protection function of the generator sets, the source of the current/voltage waveforms injected into the generator and the auxiliary protection system can be the actual test value from the power unit, or the calculation result of the computer model with sufficient accuracy, or other suitable waveforms generated by other recognized methods.

2.10.1.11 For DC power stations, if the bus coupler breaker between the main busties is a solid-state switch that meets the requirements of 2.6.1.2, a dynamic analysis report may not be required.

Section 11 Transformers/Sensors

2.11.1 General Requirements

2.11.1.1 The current/voltage transformers, sensors/transmitters used in the closed bustie shall be sufficiently reliable.

2.11.1.2 The secondary side of the transformer shall be reliably grounded.

2.11.1.3 The transformer/sensor shall have sufficient accuracy and sensitivity to accurately measure the signal value and state change.

2.11.1.4 In the design, failure modes including secondary coil failure and magnetic saturation shall be taken into account, and corresponding measures shall be taken to prevent protection failure or malfunction. During transformer selection, refer to the maximum voltage and current values during power station faults to ensure transformers do not saturate.

Section 12 Control System

2.12.1 General Requirements

2.12.1.1 The control system in this section refers to the system composed of functions and networks such as AGPS, protection relays, PMS, propulsion control system and fault ride-through auxiliary measures, such as related monitoring, self-diagnosis, logical judgment, actuators, etc.

2.12.1.2 The control system network shall be redundant and reliable. Single failures, such as disconnection, short circuit, grounding, data storm, switch failure, etc., shall not result in a result exceeding WCFDI. The integrators/suppliers of the switchboard, PMS, AGPS, AVR, etc. shall coordinate to ensure that the communication speed of the control system network meets the relevant protection, management, monitoring and alarm requirements.

2.12.1.3 The basic performance of the control system shall at least meet the relevant requirements specified in Chapter 2, Part 7 of *Rules for Classification of Sea-Going Steel Ships*.

Chapter 3 Failure Mode and Effect Analysis (FMEA)

Section 1 General Provisions

3.1.1 General Requirements

3.1.1.1 Based on the actual design, configuration and layout of the ship, the closed bustie DP system requires an FMEA completed by an independent third party. The FMEA is used to identify and qualitatively evaluate the severity of a single failure and its impact on equipment, personnel, environment and production.

3.1.1.2 The FMEA report shall be submitted to CCS for approval before the sea test. After the sea test, it shall be updated and resubmitted for approval.

Section 2 Scope and Process

3.2.1 General Requirements

3.2.1.1 For AC power stations, the FMEA shall include the following contents:

(1) Diesel generator system and governor/voltage regulator (including AGPS);

(2) Power station control, synchronization operations, insulation monitoring (low voltage and DC power stations), and protection against short circuit, grounding, phase imbalance, sudden loading and unloading;

(3) Daily transformers and auxiliary systems;

(4) Propulsion system and protection (propulsion inverter, transformer, steering system, auxiliary system, control system);

(5) DP-related auxiliary systems including fuel, lubricating oil, cooling water, compressed gas, ventilation, air conditioning, temperature control valves, pressure switches, and communications;

(6) Safety systems including emergency shutdown, fixed fire protection, liquid level telemetry/valve remote control, and their fail-safe design concepts;

(7) Auxiliary systems such as ventilation and cooling systems of the power battery compartment;

(8) DP/AGPS/PMS/AMS/BMS systems and network and communication systems (if any);

(9) Fault ride-through and quick recovery capabilities;

(10) Fire/watertight separation of the above systems (applicable to DP-3);

(11) Possible hidden failures of the above equipment/systems.

3.2.1.2 For DC systems, FMEA shall also include:

(1) Inverters (including DC/AC, AC/DC, DC/DC) and their auxiliary systems, as well as control power supplies;

(2) Solid-state switches, disconnectors and fuses;

(3) Coordinated protection logic (including AC power station);

(4) Protection against power station short circuit, overload, undervoltage, reverse power (if any), etc.;

(5) DP/EMS/BMS/AMS/IAS systems and communication networks;

(6) Reactors and filters.

3.2.1.3 The basic process of FMEA is as follows:

(1) Establish system boundaries and list all subsystems and equipment that need to be analyzed;

(2) Identify the failure mode of each component/subsystem;

(3) Identify and record the key failure mode of each component/subsystem;

(4) Describe the main components of all systems;

(5) Construct functional block diagrams to show the interactions between them;

(6) Important the single failures on all active parts;

(7) Determine the most likely causes predicted for each failure mode;

(8) Identify the transient effect of each failure on the ship's position, that is, the consequences;

(9) Identify the methods for detecting the occurrence of failures;

(10) The impact of failures on the operating capabilities of the rest of the system;

(11) Identify the common utilities such as power, lubricating oil, fuel oil, hydraulic oil, cooling water/air systems, and identify hidden/common failure modes;

(12) If some parts of the system are determined to be non-redundant and redundancy is not possible, determine mitigation factors in terms of reliability and mechanical protection;

(13) Determine the test plan to be conducted during sea test to demonstrate the redundancy established in FMEA.

Section 3 Failure Modes

3.3.1 General Requirements

3.3.1.1 The failure modes that need to be considered for the DP system based on AC closed bustie include but are not limited to:

(1) Failure modes of generator sets:

① AVR control power supply failure;

② Excitation current monitoring failure;

③ AVR operation power supply failure;

④ Other AVR failures leading to undervoltage/overvoltage;

⑤ AVR communication failure (if any);

⑥ Governor sensor signal failure;

⑦ Throttle adjustment mechanism failure;

⑧ Governor power supply failure;

⑨ Governor failure;

⑩ Overfuel or underfuel failure caused by other reasons;

⑪ Governor communication failure (if any);

⑫ Synchronization failure.

(2) Failure modes of short-circuit protection:

① Generator short circuit;

② Bustie short circuit;

③ Bus coupler cable short circuit;

④ Feeder loop short circuit.

(3) Failure modes of grounding protection:

① Generator grounding;

② Bustie grounding;

③ Bus coupler cable grounding;

④ Feeder loop grounding.

(4) Failure modes of phase imbalance protection:

① Generator phase imbalance;

② Bustie phase imbalance;

③ Bus coupler cable phase imbalance;

④ Feeder loop phase imbalance.

(5) Failure modes of underfrequency/overfrequency, and undervoltage/overvoltage:

① Short circuit;

② Grounding;

③ Sudden loading and unloading.

(6) Network failure:

Control and communication network failures related to DP/AGPS/AMS/IAS/protection/BMS/PMS (including short circuit, disconnection, grounding, data storm).

(7) Failures of fault ride-through auxiliary equipment (UPS/contactor/relay).

3.3.1.2 The failure modes that need to be considered for the DP system based on DC closed bustie include but are not limited to:

(1) Power supply failure (including generator set and battery);

(2) Failure modes of short-circuit protection:

① Bustie short circuit;

② Bus coupler cable short circuit;

③ Feeder loop short circuit.

(3) Ground insulation;

(4) DC switchboard (including converter, disconnector, etc.);

(5) Control and communication network failures related to DP/AGPS/AMS/IAS/BMS/PMS/protection (including short circuit, disconnection, grounding, data storm);

(6) Filters and reactors.

Section 4 Report Update and Submission

3.4.1 General Requirements

3.4.1.1 After the sea test has been conducted on the ship, the report needs to be updated and

resubmitted to CCS for approval in combination with the test results.

3.4.1.2 If relevant system improvements are made during operation, the report needs to be updated and submitted for approval, and the improvement needs to be tested and verified.

Chapter 4 Trials and Tests

Section 1 General Provisions

4.1.1 General Requirements

4.1.1.1 In this guideline, tests include dock tests and sea tests, collectively referred to as shipboard tests. Test methods include shipboard simulation tests and shipboard practical tests.

4.1.1.2 In addition to the trails and tests required in the definition of 1.1.3.1, shipboard practical tests shall be conducted to verify insulation monitoring, sudden loading and unloading, AGPS, quick recovery functions, etc., and the results shall be recorded.

4.1.1.3 Before the shipboard test, it is necessary to conduct detailed debugging and parameter settings for various equipment and systems, controllers, sensors, networks, etc. including generators and thrusters in combination with the dynamic analysis report and the parameters provided by the equipment manufacturer to ensure that they can meet the test requirements and test purposes. During the shipboard test, the online generator and load shall be configured in DP mode. The shipboard practical test can select the typical DP mode, such as the minimum number of online generators designed for different busties. When the power distribution form of the main generator sets with different rated powers are connected in parallel on the closed bustie main busbar, shipboard practical test shall include online conditions for both the maximum and minimum generator sets.

4.1.1.4 Tests and test procedures need to be approved by CCS. Before the test, a thorough risk assessment (HAZID analysis) shall be conducted on various test contents and operation steps to ensure the safety of test personnel and environment, meet the requirements of test conditions in the test procedures, and avoid equipment damage due to tests as much as possible.

4.1.1.5 If the test verification procedure is developed by a third party of FMEA, it shall be reviewed and confirmed by the integrator/supplier/shipyard related to the power station/power system before submission to CCS for approval to ensure the feasibility and accuracy of the test.

4.1.1.6 The shipboard simulation test shall include the simulation of the main protection and backup protection. The input of the simulation shall be based on the dynamic analysis results and input waveform selection principles in Section 10 of Chapter 2. In the shipboard practical test, the main protection may not be activated, and only the backup protection is verified, but the main protection shall have a response time record as proof of action.

4.1.1.7 The record of the test results shall be complete and can be replayed. It is preferable to use a dedicated system for result recording, including the response time of protective actions, response sequence, trigger value, equipment status, trigger alarm record, etc.

4.1.1.8 After the test, all test equipment and connections installed temporarily shall be removed, and any changed protection settings shall be restored to the correct value according to the approved protection coordination analysis report.

Section 2 Test Content

4.2.1 General Requirements

4.2.1.1 The test content shall at least include the protection functions that need to be tested and verified as mentioned in Chapter 2, including but not limited to the following:

(1) Governor failures and protection functions:

① Communication failure (if any);

② Governor signal failure;

③ Governor power supply failure;

④ Throttle adjustment mechanism failure;

⑤ Overfuel or underfuel failure caused by other reasons;

⑥ Active power distribution failure;

⑦ Verification of generator protection capability under the minimum number of online generators allowed by the design;

⑧ AGPS and governor communication failure.

Note: The above requires shipboard practical test at sea, and similar tests can be conducted together.

(2) Voltage regulator failures and protection functions:

① AVR control power supply failure;

② Excitation current monitoring failure;

③ AVR operation power supply failure;

④ Other AVR failures leading to undervoltage/overvoltage;

⑤ Other AVR abnormalities (if any);

⑥ Communication failure (such as loss of voltage signal);

⑦ Reactive power distribution failure;

⑧ Synchronization failure;

⑨ Verification of generator protection capability under the minimum number of online generators allowed by the design;

⑩ AGPS and voltage regulator communication failure.

Note: The above requires shipboard practical test at sea, and similar tests can be conducted together.

(3) Short-circuit protection:

① Generator short circuit;

② Bustie short circuit;

③ Bus coupler cable short circuit;

④ Feeder loop short circuit.

Note: According to the definition in 1.3.1.1, the shipboard practical test at least includes short circuit test of the main bustie.

(4) Grounding protection:

① Generator grounding;

② Bustie grounding;

③ Bus coupler cable grounding;

④ Feeder loop grounding.

Note: According to the definition in 1.3.1.1, the shipboard practical test at least includes grounding test of the main bustie.

(5) Phase imbalance protection:

① Generator phase imbalance;

② Bustie phase imbalance;

③ Bus coupler cable phase imbalance;

④ Feeder loop phase imbalance.

Note: According to the definition in 1.3.1.1, the shipboard simulation test at least includes phase imbalance test of the main bustie.

(6) Sudden loading and unloading;

Note: The shipboard practical test at sea is required. Under the typical power distribution mode, the typical load is at least a single unit and a single thruster.

(7) Quick recovery test:

① Simulate the power loss of a single main bustie in automatic control mode and record the system/equipment response process and time;

② The time meets the requirements of 2.7.1.5.

Note: The shipboard practical test at sea. The test of the main busbar of the main generator sets with different rated powers connected in parallel shall be included.

(8) Fault ride-through test:

① Bustie three-phase short circuit;

② Bustie grounding failure.

Note: Shipboard tests are required, providing response and time records for equipment with ride-through capabilities.

(9) Communication network test:

① Network short circuit and disconnection failure;

② Network data storm failure.

Note: The shipboard simulation test at sea is required.

(10) Power management system:

Verify the impact of power management system failure (UPS, PLC, misoperation, etc.) on power station management and rapid startup.

Note: The shipboard practical test at sea is required.

(11) Load oscillation test between units;

Note: The shipboard practical test at sea is required.

(12) Insulation monitoring system (low voltage system);

Note: The shipboard simulation test is required.

4.2.1.2 For DC power stations, in addition to the applicable contents of 4.2.1.1, the tests shall also include:

(1) Short circuit support analysis report of daily inverters;

(2) Insulation monitoring system;

(3) Failures of solid-state switches and disconnectors.

Note: The shipboard simulation test is required.

Chapter 5 Post-construction Survey

Section 1 General Provisions

5.1.1 General Requirements

5.1.1.1 For the post-construction survey of DP and DP-related equipment, refer to the in-service survey and test contents of Part 1 of the *Rules for Classification of Sea-Going Steel Ships*.

5.1.1.2 During the special survey of ships, in addition to referring to the special survey contents of Part 1 of the *Rules for Classification of Sea-Going Steel Ships*, test contents of the corresponding class notation shall also include the requirements of Chapter 4. The test procedures shall be approved by the on-site surveyor in advance, and the test shall be witnessed by the surveyor on site.

5.1.1.3 If the ship experiences automatic tripping, partial power loss, recovery failure, ride-through failure, etc., the cause shall be found and recorded during operation, and CCS shall be notified in writing for evaluation.

Appendix A Recommended Protection Functions

ANSI Code	Protection functions	Protection objects				
		Generator and switch	Bus coupler	Daily transformer power supply switch	Thruster circuit power supply switch	Tie switch (if required)
25	Synchronization	×	×			×
32	Reverse power	×				
27	Undervoltage	×	×			×
40	Underexcitation	×				
46	Phase imbalance	×	×	×	×	×
49	Winding temperature	×		×	×	
50	Instantaneous trip due to short circuit	×		×	×	
51/51V	Overload/overcurrent	×	×	×	×	×
59	Overvoltage	×	×			
87BB	Bustie differential		×			×
67BB	Bustie short circuit		×			×
67BBNS	Bustie grounding fault direction protection		×			×
67G	Generator grounding protection	×				
67Ns	Grounding fault directional protection		×	×	×	×
81O	Overfrequency	×	×			×
81U	Underfrequency	×	×			×
86	Locking	×	×	×	×	×
87G	Generator differential	×				
87L	Cable differential		×			×
87NsL	Cable grounding		×			×
74TC	Circuit breaker monitoring circuit	×	×	×	×	×
Sensor	Arc protection		×			×
60FL	Voltage transformer fuse	×	×	×	×	×
50BF	Circuit breaker fault protection	×	×	×	×	
U0>	Displacement voltage alarm	×	×			×
1>>>	Fault connection	×	×	×	×	