

Supplementary Material

a/a	Failure	λ [hour ⁻¹]	Source	β [-]	source for β factors	DEP subsystem
1	Earth faults in D/G set	2.79E-06	[1]	1.3	[2]	D/G set
2	Overcurrent in D/G set	2.79E-06	[1]	1.3	[2]	D/G set
3	Differential current fault in D/G set	2.79E-06	[1]	1.3	[2]	D/G set
4	Short circuit in D/G sets	2.79E-06	[1]	1.3	[2]	D/G set
5	Engine failure	1.77E-03	[1]	1	No data	D/G set
6	Failure to start on demand the engine	1.80E-03	[1]	NA	NA	D/G set
7	Failure to start on demand the generator	4.80E-03	[1]	NA	NA	D/G set
8	D/G set thrust bearings failure	2.78E-06	[1]	1.3	[2]	D/G set
9	D/G set main bearings failure	2.78E-06	[1]	1.3	[2]	D/G set
10	Water pipelines on engine failure	1.18E-05	[1]	1.24	[3]	D/G set
11	Engine air supply failure	3.01E-06	[1]	1	No data	D/G set
12	Lubricating oil pipelines failure	7.47E-08	[1]	1.24	[3]	D/G set
13	Lubricating oil filter failure	3.35E-10	[1]	1.1	[2]	D/G set
14	High lub oil mist presence in engine cranckcase	1.72E-05	[1]	1.24	[2]	D/G set
15	Turbocharger failure	4.74E-09	[1]	1.3	[2]	D/G set
16	Engine exhaust valves failure	1.87E-08	[1]	2.23	[4]	D/G set
17	Engine injection system failure	2.34E-08	[1]	1.552	[5]	D/G set
18	D/G set controller hardware failure	3.77E-06	[1]	NA	NA	D/G set

19	D/G set controller not starting the D/G set when required	5.00E-05	[6]	NA	NA	D/G set
20	D/G set controller not synchronising the D/G set when required	1.00E-05	[6]	NA	NA	D/G set
21	D/G set controller implementing extra attempts to synchronise	1.00E-05	[6]	NA	NA	D/G set
22	D/G set controller not coordinating AVR and D/G set controller as required	1.00E-05	[6]	NA	NA	D/G set
23	D/G set controller software faulty failure to coordinate Governor and D/G controller	1.00E-05	[6]	NA	NA	D/G set
24	D/G set controller implementing wrong starting sequence	1.00E-05	[6]	NA	NA	D/G set
25	D/G set controller starting D/G set longer than required	1.00E-05	[6]	NA	NA	D/G set
26	D/G set controller providing wrong reference speed during start	1.00E-05	[6]	NA	NA	D/G set
27	D/G set controller providing too fast speed increase command	1.00E-05	[6]	NA	NA	D/G set
28	D/G controller communication lines failure	2.50E-08	[7]	NA	NA	D/G set
29	Generator frequency sensors failure	1.19E-06	[1]	NA	NA	D/G set
30	Turning gear status sensor failure	1.40E-06	[6]	NA	NA	D/G set
31	Fuel temperature sensor failure	3.77E-06	[1]	NA	NA	D/G set
32	Fuel pressure sensor failure	1.25E-06	[1]	NA	NA	D/G set
33	Lubricating oil level sensor failure	1.40E-06	[6]	NA	NA	D/G set
34	Air starting system air pressure sensors failure	5.32E-06	[1]	NA	NA	D/G set
35	Governor hardware faulty	3.77E-06	[1]	NA	NA	D/G set
36	Governor not responding to changes	1.00E-06	[8]	NA	NA	D/G set
37	Governor fails to synchronise to network	1.00E-06	[8]	NA	NA	D/G set
38	Governor communication lines failure	2.50E-08	[7]	NA	NA	D/G set
39	Governor speed sensors erroneous measurement	1.18E-05	[1]	NA	NA	D/G set

40	Governor fuel rack pumps failure	#REF!	[1]	1.1	[2]	D/G set
41	Governor fuel limiter failure	6.27E-07	[1]	NA	NA	D/G set
42	AVR fails to synchronise to network	1.00E-06	[8]	NA	NA	D/G set
43	AVR does not change the voltage level when required	1.00E-06	[8]	NA	NA	D/G set
44	AVR voltage sensor erroneous measurement	5.08E-07	[1]	NA	NA	D/G set
45	AVR hardware failure	1.11E-05	[1]	NA	NA	D/G set
46	AVR excitation bridge failure	2.63E-07	[1]	1	No data	D/G set
47	AVR communication failure	2.50E-08	[7]	NA	NA	D/G set
48	Engine safety system hardware failure	1.00E-05	[6]	NA	NA	D/G set
49	Engine safety system fault tripping of engine	1.00E-05	[6]	NA	NA	D/G set
50	Engine safety system not tripping the D/G set when required	5.00E-04	[6]	NA	NA	D/G set
51	Engine safety system tripping the D/G set with delay when required	5.00E-04	[6]	NA	NA	D/G set
52	Engine safety sytem lubricating oil pressure sensors failure	1.25E-06	[1]	NA	NA	D/G set
53	Engine safetys system high thrust bearings temperature sensors failure	3.77E-06	[1]	NA	NA	D/G set
54	Engine safety system cooling water temperature sensors failure	3.77E-06	[1]	NA	NA	D/G set
55	Engine safety system exhaust gas temperature sensors failure	3.77E-06	[1]	NA	NA	D/G set
56	Engine safety system main bearings temperature sensors failure	3.77E-06	[1]	NA	NA	D/G set
57	Engine safety system oil mist detector sensor failure	5.80E-07	[9]	NA	NA	D/G set
58	Engine safety system speed sensor failure	1.88E-06	[1]	NA	NA	D/G set
59	Engine safety system actuator failure	1.30E-06	[6]	1.1	[2]	D/G set
60	Engine safety system communication failure	2.50E-08	[7]	NA	NA	D/G set

61	Generator safety system hardware failure	1.00E-05	[6]	NA	NA	D/G set
62	Generator safety system not tripping the D/G set when required	5.00E-04	[6]	NA	NA	D/G set
63	Generator safety system generator faulty tripping	1.00E-05	[6]	NA	NA	D/G set
64	Generator safety system current sensor failure	5.32E-07	[10]	NA	NA	D/G set
65	Generator safety system frequency sensor failure	8.82E-07	[1]	NA	NA	D/G set
66	Cylinders failure	1.68E-10	[1]	NA	NA	D/G set
67	D/G set fuel pump failure	3.35E-10	[1]	NA	NA	D/G set
68	D/G set shaft failure	1.68E-10	[1]	NA	NA	D/G set
69	Engine piston failure	2.61E-06	[11]	1.552	[5]	D/G set
70	Governor speed sensors failure	2.37E-05	[1]	NA	NA	D/G set
71	AVR voltage sensor failure	5.08E-07	[1]	NA	NA	D/G set
72	Engine safety system faulty tripping the engine due to alleged high oil mist concentration	7.39E-06	Accident investigation report	1	No data	D/G set
73	Failure of current sensors on D/G set	5.32E-07	[10]	NA	NA	D/G set
74	Failure of voltage sensors on D/G set	6.73E-07	[1]	NA	NA	D/G set
75	Lubricating oil pump failure	1.01E-11	[1]	1.2	[2]	Engine auxilliary system
76	Starting air system failure	6.28E-06	[1]	1	No data	Engine auxilliary system
77	Fuel supply system during start failure	6.27E-07	[1]	1	No data	Engine auxilliary system
78	Water cooler failure	2.51E-06	[1]	1.88	[12]	Engine auxilliary system

79	Fuel pipes failure	1.34E-05	[1]	1.24	[3]	Engine auxilliary system
80	Engine fuel filter failure	3.35E-10	[1]	1.1	[2]	Engine auxilliary system
81	Engine high temperature water pump failure	3.02E-05	[1]	1.2	[2]	Engine auxilliary system
82	Engine low temperature water pump failure	3.02E-05	[1]	1.2	[2]	Engine auxilliary system
83	Generator low temperature water pump failure	1.02E-06	[1]	1.2	[2]	Engine auxilliary system
84	Oil cooler failure	1.34E-05	[1]	1.88	[12]	Engine auxilliary system
85	Fuel supply pump failure	7.56E-06	[13]	1.2	[2]	Engine auxilliary system
86	Fuel filter in supply system failure	6.96E-06	[13]	1.1	[2]	Engine auxilliary system
87	Fuel heater failure	4.27E-06	[13]	1.552	[5]	Engine auxilliary system
88	Fuel booster pump failure	8.28E-06	[13]	1.2	[2]	Engine auxilliary system
89	Sea chest clogged	7.00E-04	[14]	1.3	[2]	Engine auxilliary system
90	Quick fuel valve faulty tripping	1.00E-05	[6]	NA	NA	Engine auxilliary system
91	Electrical transient is not acceptable by the system	3.35E-08	Accident investigation report	NA	NA	General
92	Fire in engine room	6.60E-07	[15, 16]	NA	NA	General
93	Failure in communication lines	2.50E-08	[7]	NA	NA	General

94	Intelligent diagnosis does not identify and correct load sharing	1.00E-02	Assumption	NA	NA	Intelligent Diagnosis
95	Failure of Intelligent Diagnosis hardware	3.02E-05	[1]	NA	NA	Intelligent Diagnosis
96	Short circuit in air conditioning motors	3.28E-07	[1]	1.3	[2]	Other
97	Arc in switchboards	1.14E-08	[17]	1.3	[2]	Other
98	Short circuits in transformers	4.81E-07	[7, 18]	1.3	[2]	Other
99	D/G set, Bus-Tie, Air conditioning motors, Bow Thrusters circuit breaker not operating	2.50E-06	[19]	NA	NA	Other
100	D/G set, Bus-Tie, Air conditioning motors, Bow Thrusters, circuit breaker spurious operation	1.20E-06	[19]	NA	NA	Other
101	Transformer failure	1.75E-06	[7]	1.93	[20]	Other
102	Arc protection hardware failure	1.50E-05	[1]	NA	NA	Other
103	Arc protection software not operating	5.00E-04	[6]	NA	NA	Other
104	Arc protection sensors failure	5.80E-07	[9]	NA	NA	Other
105	Fault tripping of arc protection	1.50E-05	[1]	NA	NA	Other
106	PMS hardware faulty	1.50E-05	[6]	NA	NA	PMS
107	Failure to reduce the propulsion motors load	5.00E-05	[6]	NA	NA	PMS
108	Failure to reduce the propulsion motors load in time	5.00E-05	[6]	NA	NA	PMS
109	Failure to trip heavy consumers	5.00E-05	[6]	NA	NA	PMS
110	Fault tripping of propulsion motors	1.00E-05	[6]	NA	NA	PMS
111	PMS Failure to start a D/G when required	1.00E-05	[6]	NA	NA	PMS
112	PMS starting an already running D/G set	1.00E-05	[6]	NA	NA	PMS
113	PMS starting a faulty D/G set	1.00E-05	[6]	NA	NA	PMS

114	PMS stopping D/G set without other set allocation	1.00E-05	[6]	NA	NA	PMS
115	PMS connecting bus-tie breaker to a section with electrical fault	1.00E-05	[6]	NA	NA	PMS
116	PMS starting a D/G set with delay	5.00E-05	[6]	NA	NA	PMS
117	PMS allowing load increase, when inadequate D/G set number is connected	1.00E-06	[6]	NA	NA	PMS
118	Short circuit in propulsion motors or bow thrusters	3.28E-07	[1]	1.3	[2]	Propulsion motors
119	Overcurrent in propulsion motors	2.79E-06	[1]	1.3	[2]	Propulsion motors
120	Differential current fault in propulsion motors	2.79E-06	[1]	1.3	[2]	Propulsion motors
121	Application controller not reducing propulsion motors load during D/G sets overload conditions	5.00E-05	[6]	NA	NA	Propulsion motors
122	Application controller generates unacceptable electrical transients during start of propulsion motors	5.00E-05	[6]	NA	NA	Propulsion motors
123	Application controller not timely reducing propulsion motors load during D/G sets overload conditions	5.00E-05	[6]	NA	NA	Propulsion motors
124	Faulty tripping of propulsion motors by application controller	1.00E-05	[6]	NA	NA	Propulsion motors
125	Application controller not controlling power increase	1.00E-05	[6]	NA	NA	Propulsion motors
126	Drive controller not reducing propulsion motors load during D/G sets overload conditions	1.00E-06	[8]	NA	NA	Propulsion motors
127	Drive controller not timely reducing propulsion motors load during D/G sets overload conditions	1.00E-06	[8]	NA	NA	Propulsion motors
128	Drive controller not controlling power increase	1.00E-05	[8]	NA	NA	Propulsion motors

129	Temperature sensors on cycloconverter failure	3.63E-06	[1]	NA	NA	Propulsion motors
130	Temperature sensors on winding of motors failure	2.63E-07	[1]	NA	NA	Propulsion motors
131	Temperature sensors on cooling water system of propulsion motors failure	2.63E-07	[1]	NA	NA	Propulsion motors
132	Temperature sensors on bearings of propulsion motors failure	2.63E-07	[1]	NA	NA	Propulsion motors
133	Speed sensors on propulsion motors failure	2.63E-07	[1]	NA	NA	Propulsion motors
134	Radial bearings on motors failure	3.28E-07	[1]	1.3	[2]	Propulsion motors
135	Propulsion motors air supply system failure	2.63E-06	[1]	1.2	Assumption	Propulsion motors
136	Propulsion motors water cooling system failure	2.30E-06	[1]	1.2	Assumption	Propulsion motors
137	Electrical motor failure	4.38E-05	[1]	1.2	[2]	Propulsion motors
138	Electrical motor shaft failure	1.00E-06	Assumption	2	[2]	Propulsion motors
139	Sealing on azipods failure	2.92E-05	[21]	1.4	[2]	Propulsion motors
140	Load (current and voltage) sensors on azipods	2.63E-07	[1]	NA	NA	Propulsion motors
141	Rectifier failure	4.34E-06	[1]	1	No data	Propulsion motors
142	Converter failure	1.43E-04	[1]	1	No data	Propulsion motors

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