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BEHAVIOUR OF MARINE ELECTRO GENERATORS UNDER ABNORMAL CONDITIONS USING ENGINE CONTROL ROOM SIMULATOR

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Abstract

The aim of the present paper is to analyze the behaviour of diesel engine driven electro generators used in maritime engineering for the electrical power supply system of ship on real time operation and under abnormal conditions. Two generators that are driven by diesel engines, modelled as high speed engines with all vital subsystems such as governor, sea water system, cooling water – lubrication oil, start air, turbo charge, air cooler, fuel oil. Besides, the research attempts to provide solutions for real operating problems and to test the reactions of personnel that are responsible for the normal function of generators. These solutions will give a quantitative description of the work and it will form a basis to reveal the most important risk factors. Simulator exercises have been defined to reflect some of these options.

Key words: Engine Room Simulator, Generators, Faults, Maintenance.

INTRODUCTION

Today, the extended use of innovative educational tools such as marine engine and bridge simulators allows us to test new technology before implementing it on board. Also, the main aim of the simulator (S.T.C.W., 1995; IMO Model Course 2.07, 2002) is to assist manufacturers and maritime training institutes – academies and their teaching staff in organizing and introducing new training courses or in

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enhancing, updating or supplementing existing training and research material where the quality and effectiveness of the knowledge and experience may thereby be improved.

The simulator exercises could be used as far as practically reasonable to quantify:

— work load, fatigue,
— stress levels
— and available time for watch out.

Parameters to be quantified include number of operations carried out and time used on different tasks.

Misunderstandings (in the man-machine interaction as well as in human-human communication), loss of situation awareness and erroneous planning and execution will be identified as occurring will form a basis to reveal the most important risk factors and to identify hazards. Besides, simulator exercises (I.M.O., Model Course 2.07, 2002; Kluj, 1997) allow the trainees to become familiar with the instrumentation and controls used in the engine rooms of modern merchant ships, as well as, develop the ability to become skilled in the scanning of faults that can occur during the operation plant.

It is a well known that one from the most critical systems for the normal operation of ship is the effective operation without malfunctions of electro generators. The careful use of generators, in combination, with the equitable and periodical maintenance, using suitable checklists (Kluj, 1999), can lead to decreased appearance of total blackout. Under unfortunate conditions a blackout can endanger the safety of ship, leading to grounding or collision. A non planned blackout should therefore be regarded as an emergency situation and treated likewise.

For this purpose the influence of vital subsystems (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999) such as governor, sea water system, cooling water – lubrication oil, start air, turbo charge, air cooler, fuel oil on the normal operation of diesel electro generators, have been studied.

An attempt to examine the basic malfunctions of diesel electro generators and especially how they are could be avoided has been made. This paper discusses some of the faults of such systems and provides an insight into the various technical issues associated with the application and maintenance of electrical power systems for marine applications.

LIST OF SYMBOLS

Mxx	Malfunction xx
ALxx	Alarm xx
EBMxx	Event based malfunction xx

DESCRIPTION OF SIMULATOR

The engine room simulator plant at Merchant Marine Academy of Makedonia is designed, implemented and integrated by Kongsberg Nor control Simulation (Kongsberg Nor control, PPT2000-MC90-III, 1999).

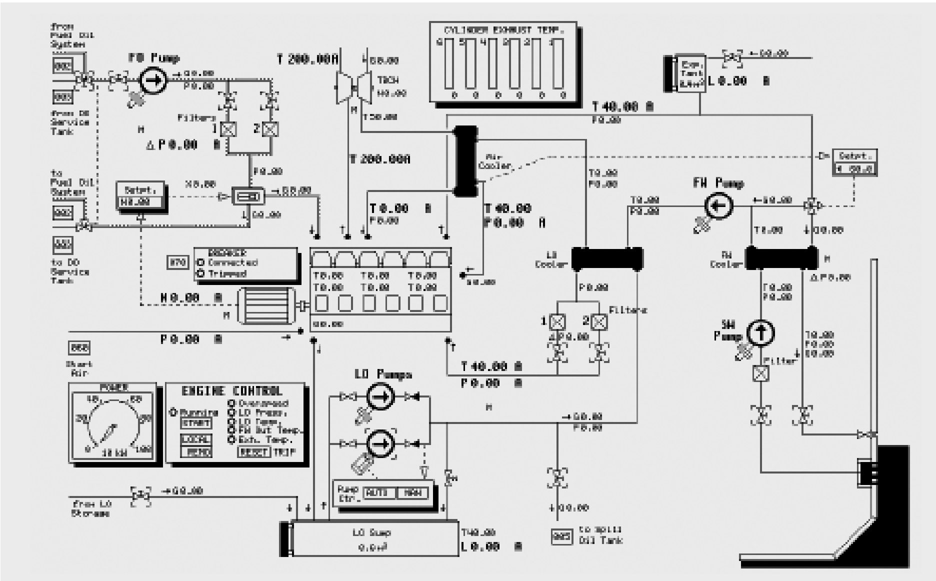
The simulator could be divided into two main parts: The simulated Engine Room and the Instructor system. The simulated engine room is arranged as subsystems identical to those found onboard a real Very Large Crude Oil Carrier Ship (V.L.C.C.). The simulation models have been configured by Operator Training Industrial Simulation System software that it has been developed by Special Analysis and Simulation Technology Ltd, England.

Simulator training or research projects of Merchant Marine Academy of Makedonia are realized by the following phases:

1. Proposal Phase,
2. Data collection and implementation,
3. Simulation and data recording,
4. Analysis
5. Reporting.

The instructor system of engine room simulator comprises the facilities and features needed for the instructor to prepare, control and evaluate the simulator training courses or research studies.

Figure 1: Diesel engine driven generator.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual, The simulated main engine is a B&W 5L90 MC, five cylinder in-line, low speed, two stroke engine with turbo-charging and scavenging air cooling.

Generators are driven by diesel engines [Figure 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)], modelled as high speed engines with all vital subsystems such as rpm governor, cooling water, lubrication oil, start air, turbo charger, air cooler and fuel oil.

The electrical consumption is monitored and compared to the present possible power production. When deviation from present limits arises, the system will act in order to normalize the situation. The system also performs continuous controls of the frequency and load sharing.

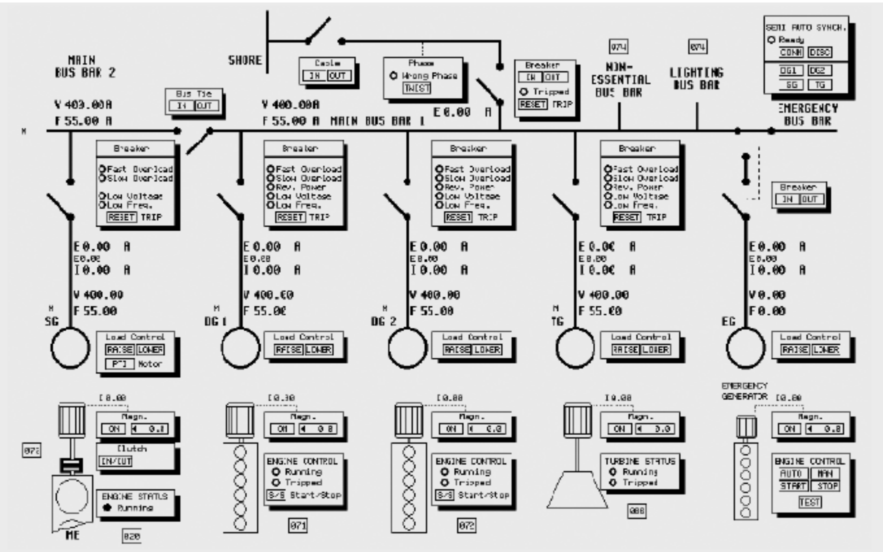
The preferred mode of operation is with Shaft generator as base generator, the turbo generator as an auxiliary generator and with two diesel generators in auto as stand by generators.

The ship's electric distribution [Figure 2, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] is grouped in 2 separate bus bar sections:

— Main Bus Bar 1 is powered by the diesel generators and turbo-generator. The shore supply is also connected to this bus bar. All main consumers are fed from this section.

— Main Bus Bar 2 is powered by the shaft generator. It is normally isolated from the bus bar 1 by a bus tie breaker. The consumers connected to bus bar 2 are all insensitive to frequency/voltage variations and hence are suitable for shaft generator supply.

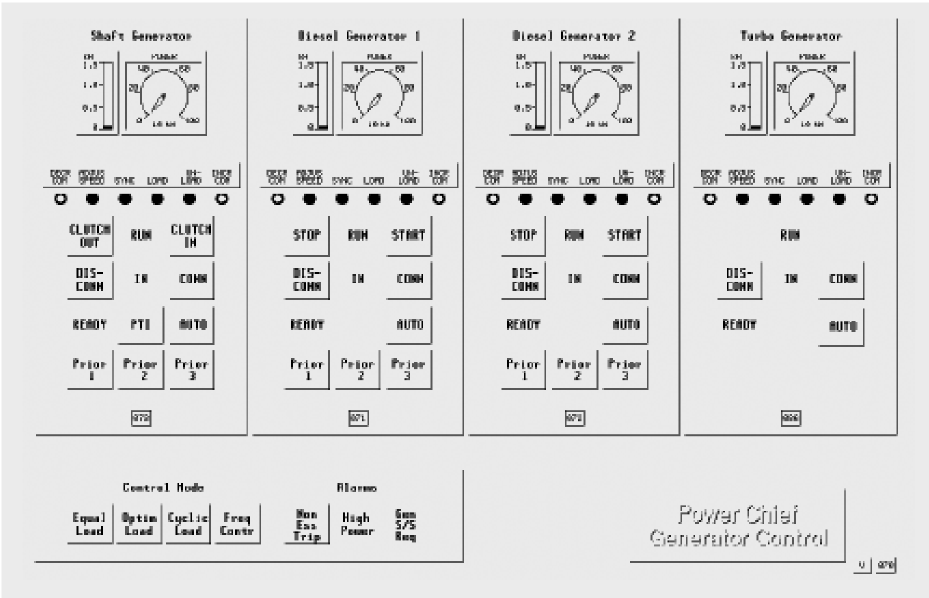
Figure 2. Electric power plant.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual.

The recommended priority setting [Figure 3, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] is priority 1 for the Shaft Generator, priority 2/3 for diesel generator 1/2. Diesel generators, in case of a blackout situation, act as stand by generators. The generator with the highest priority will be the first to be connected. The generator with the highest priority will take the entire load up to 70% of normal rating, while the other generator takes the rest of the load. The load limits for the highest priority generators are 680 to 800 *kW*.

Figure 3. Power chief Generator control.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

Due to the difference in the torque characteristics of the generators, it was not possible to keep the same load sharing over the whole power range except by manual readjustment or by control action from the power chief system.

The system has two load sharing concepts:

— balanced (symmetrical)

— unbalanced (asymmetrical)

For sharing of the load between the generators sets which are connected to the same bus bar. When the balanced mode is selected the system ensures that the load of each generator has the same power ratio (percentage of maximum load). When two diesel electro generators are connected to the bus bar 1 and the unbalanced mode is selected the system ensures that the load of one generator has a specified ration while the other act as a topping up with a minimum load.

The unbalanced load sharing system could serve at least two purposes. One purpose is to optimize the load on one diesel generator with respect to economy while the second diesel generator will handle the remaining load. Another purpose is to protect a newly overhauled auxiliary diesel engine by ensuring a certain maximum load to it.

Table 1. Alarms of Diesel Generators.

	High
AL01	Fuel oil filter drop diesel generator
AL03	Lubrication oil temperature inlet diesel generator
AL05	Fresh water temperature outlet diesel generator
AL06	Exhaust temperature outlet turbo charge
AL07	Exhaust temperature inlet turbo charge
AL08	Bearings temperature diesel generator

	Low
AL02	Lubrication oil pressure inlet diesel generator
AL04	Fresh water pressure inlet diesel generator

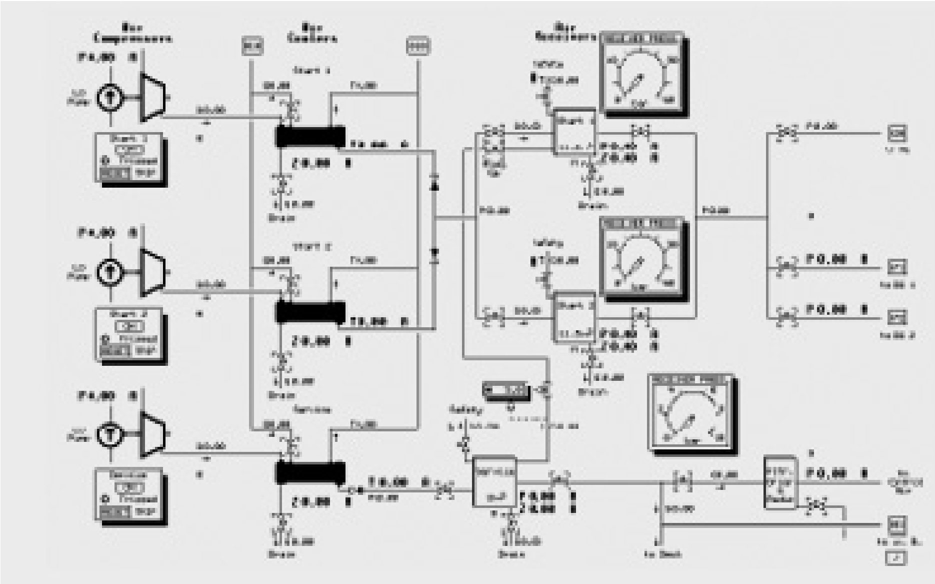
Alarms '*ALxx*' of diesel driven generators are divided into two types: high and low level alarms. Table 1 displays the alarms of diesel generators. Thus, the trouble shooting scenarios were designed to provide experience in identifying malfunctions, faults and applying remedial procedures. All operations have been planned in accordance with the established rules and procedures to ensure safety of operations.

OBSERVATION PLAN

In the examined scenario the ship was running in open sea following the mode 'Slow Ahead – Loaded'. The ambient sea water temperature was 15 ˚C, the ambient air temperature was 20 ˚C and the ambient air humidity was 50%. Sea water depth was 200 m, main engine fuel link position was 43% and the main engine speed command was 49 rpm.

The required seawater and freshwater systems for the cooling of generators have been prepared [Figure 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. Compressors [Figure 4, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] were in operation in order to supply starting and control air. Fuel oil and lubrication oil

Figure 4. Start air and air compressors.



Source: Kongsberg Norcontrol, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

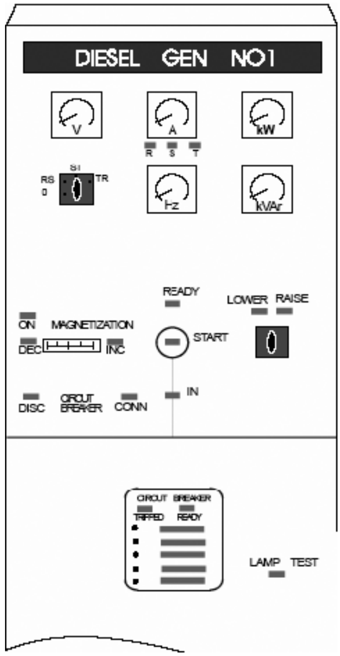
systems for the correct operation of generators also were ready. The procedures of the voltage and frequency adjustment have been followed (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999).

Figure 5 shows the control panel of diesel generators (Kongsberg Norcontrol, PPT2000-MC90-III, 1999). The identification and recording of normal cooling water temperatures exhaust gas temperatures; round per minutes and fuel data consumption data of engines as well as the produced power, voltage, current and frequency for the electrical system have been realized.

Several faults have been introduced in order to demonstrate cascading of abnormal conditions that influence the operation of diesel driven electro generators (I.M.O., Model Course 6.09, 2001; I.M.O., Model Course 2.07, 2002). In the current scenario used nine malfunctions '*Mxx*'. Faults could be edited on line. However, for each inserted malfunction the observation time was specified to be 5 minutes in order to have a stable factor for evaluation. The malfunction might be ramped from the initial value to the specified malfunction set point. Besides in our scenario has been included one event - based malfunction '*EBMxx*' that goes active depending on a specified event that occurs in the process. In general, the event based malfunction will go active if the watched variable is higher or lower than the given limits. If the variable toggles around the limits, it could be set a delay time before the malfunction is triggered.

For the demonstration of the diesel generator driven alarm *AL01* 'High Fuel oil filter drop of diesel generator', the malfunction *M01* 'Dirty diesel oil filter of diesel generator' was activated after the running of scenario. The highest limit of fuel oil filter differential pressure is 1,00 *bar*. Diesel oil filter started to be gradually dirty (0 ÷ 100%) with the use of ramp mode in 5 minutes. Figure 6 shows the appearance time of alarm *AL01* at the different stages of produced fault. From this figure it can be seen that the increase of damage over 20% does not give to personnel the adequate time for the quick re-establishment of damage. For the repair of damage [Figure 1, (Kongsberg Norcontrol, PPT2000-MC90-III, 1999)] was activated the valve for the diesel generator filter 2 and was deactivated the valve for the diesel generator filter 1.

Figure 5. Electrical control panel of diesel generator.



Source: Kongsberg Norcontrol, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

For the demonstration of the diesel generator driven alarm *AL02* 'Low Lubrication oil pressure inlet diesel generator', the malfunction *M02* 'Diesel generator lubricant oil pump 1 wear' was activated 5 minutes of simulated time after the running of scenario. The lowest limit of lubrication oil pressure inlet is 1,40 *bar*. Lubricant oil pump started to be destroyed gradually (0 ÷ 100%) with the use of ramp mode in 5 minutes. Figure 6 shows the appearance time of alarm *AL02* at the different stages of produced fault. From this figure it can be seen that for damages until 40% there is plenty of time for the re-establishment of damage. For the repair of damage [Figure 1, (Kongsberg Norcontrol, PPT2000-MC90-III, 1999)] was activated in auto mode diesel generator lubrication oil priming.

For the demonstration of the diesel generator driven alarm *AL03* 'High Lubrication oil temperature inlet diesel generator' were used one time-based malfunction and one event based malfunction. The highest limit of lubrication oil temperature inlet was 75 ℃. *M03* malfunction 'Diesel generator fresh water cooler dirty' was activated 10 minutes of simulated time after the running of scenario. Fresh water cooler of diesel generator was destroyed suddenly at 70%. The event based malfunction *EBM01* 'Closed diesel generator sea water inlet valve' was specified to be turned active when the lubrication oil temperature inlet of diesel generator exceeds 66 ℃. It can be observed that *AL03* is activated in 39 *sec*. For the avoidance of damage (Figure 1, [7]) the engineer who is doing watch keeping must inspect periodically the cleanness of fresh water coolers and checks the good operation of inlet and outlet valves of sea water for cooling of fresh water system.

For the demonstration of the diesel generator driven alarms, *AL04* 'Low Fresh water pressure inlet diesel generator' and *AL05* 'High fresh water temperature outlet diesel generator', malfunction *M04* 'Wear fresh water pump of diesel generator' was activated 15 minutes of simulated time after the running of scenario.

The lowest limit of fresh water inlet pressure is 0,70 *bar* and the highest limit of fresh water outlet temperature is 85 ℃. Attached fresh water pump started to be worn (0 ÷ 100%) with the use of ramp mode, in 5 minutes. Figure 7 shows the appearance time of alarms *AL04* and *AL05* at the different stages of produced wear. From this figure it can be observed that the increase of worn over 60% leads in the simultaneously appearance of two alarms. For the avoidance of blackout the personnel of engine room must check the circuit of fresh water of diesel generator at regular intervals in order to keep the diesel engine cooling and lubricating oil within the correct operational range.

Figure 6. Appearance time of alarm AL01 and AL02

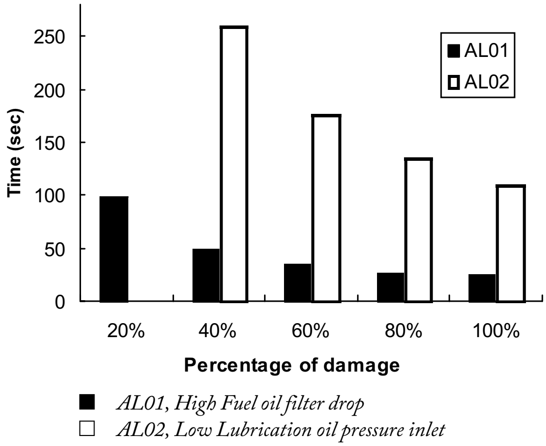
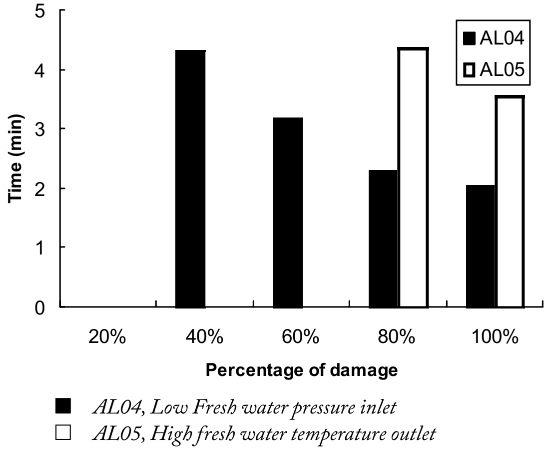


Figure 7. Appearance time of alarm AL04 and AL05



For the demonstration of the diesel generator driven alarms, *AL06* 'High diesel generator exhaust temperature outlet turbo charge' and *AL07* 'High diesel generator exhaust temperature inlet turbo charge' were used three malfunctions simultaneously. The produced faults were the next:

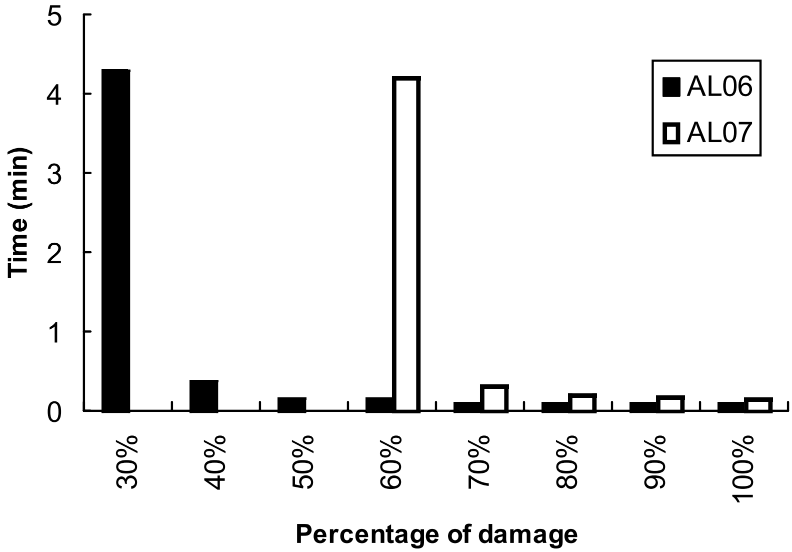
— Malfunction *M05* 'Diesel generator turbocharger dirty',
— Malfunction *M06* 'Diesel generator turbocharger air cooler dirty'
— Malfunction *M07* 'Diesel generator turbocharger air filters dirty'.

These were activated 20 minutes of simulated time after the running of scenario. The highest limits of exhaust temperatures outlet and inlet of turbocharger of diesel generator is 520 ℃ and 610 ℃ respectively. Figure 8 shows the appearance time of alarms *AL06* and *AL07* at the different stages of produced fault.

From this figure it can be observed that the critical percentage of damage for the appearance of *AL06* and *AL07* is the parallel damage of subsystems of turbocharger at 30% and 60% respectively. For bigger percentages of damage than these values it can be deduced that the response time for the re-establishment of damage is very limited.

For the demonstration of the diesel generator driven alarm *AL08* 'High diesel generator Bearings temperature diesel generator' were used two malfunctions at the same time. Malfunction *M08* 'Diesel generator lubrication oil filter 1 dirty' and malfunction *M09* 'Diesel generator lubrication oil cooler dirty'. These were activated 25 minutes of simulated time after the running of scenario. The highest limit of diesel generator bearing temperature is 85 ℃. Increasing gradually the damages, it was observed that for percentages until 40% *AL08* was not activated. The critical percentage of damage was to a value of 50% and alarm *AL08* was activated in 2:45 minutes. For biggest percentages of faults it was deduced that the occurrence of blackout of diesel generator could not be avoided.

Figure 8. Appearance time of alarm AL06 and AL07.



■ *AL06, High exhaust temperature outlet turbo charge*
□ *AL07, High exhaust temperature inlet turbo charge*

CONCLUSIONS

These experiments form part of a larger work (Gourgoulis et al., 2004) concerning the use of engine simulator that simulates a dynamic real time computerized slow speed main propulsion turbocharged diesel engine incorporating a waste heat steam boiler, a turbo generator and one shaft generator.

For the avoidance of malfunctions that influence the normal operation of diesel electro generators during the drip, daily, the operator must check the diesel oil filter of diesel generator, the lubricant oil pump, the sea water temperature control, the fresh water flow resistance, the fresh water pump, the subsystems of turbo charge air cooler and the cooling water flow of start air compressor. Thus, observing all the produced faults it was deduced that the most dangerous fault was malfunction M01 'Dirty diesel oil filter of diesel generator' and the less dangerous fault was malfunction M04 'Wear fresh water pump of diesel generator'.

Familiarisation of students with electrical shipboard systems or equipment combined with possible faults proved that students have the opportunity to develop operational skills, to combine simulations with multimedia techniques such as animation, diagrams, pictures, sound, etc, to develop and improve the English language skills of ships' personnel to make the learning process shorter with the simultaneous increase in quality and to make the assessment process of trainees much more effective.

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COMPORTAMIENTO DE GENERADORES ELÉCTRICOS MARINOS EN CONDICIONES ANORMALES UTILIZANDO UN SIMULADOR DE CONTROL DE LA CÁMARA DE MÁQUINAS

RESUMEN

El objetivo del presente trabajo es analizar el comportamiento del motor diesel, el electro generadores utilizados en ingeniería marítima para el sistema de suministro de energía eléctrica de los buques en tiempo real el funcionamiento y en virtud de condiciones anormales. Dos generadores que están impulsados por motores diesel, como el modelo de alta velocidad con los motores de todos los subsistemas vitales como gobernador, sistema de agua de mar, agua de refrigeración de aceite de lubricación, inicie el aire, la carga de turbo, el aire fresco y fuel. Además, la investigación intenta aportar soluciones para los problemas reales de funcionamiento y poner a prueba las reacciones del personal que se encarga de la función normal de los generadores. Estas soluciones cuantitativos dará una descripción de los trabajos y que servirán de base para revelar los más importantes factores de riesgo. Simulador de ejercicios se han definido para reflejar algunas de estas opciones.

INTRODUCCIÓN

Hoy en día, la extensión del uso de innovadoras herramientas educativas como motor marino y simuladores de puente nos permite probar la nueva tecnología antes de su aplicación a bordo. Además, el objetivo principal del simulador (S.T.C.W., 1995; IMO Model Course 2.07, 2002) es ayudar a los fabricantes e institutos de formación marítima de las academias y de sus profesores en la organización y la introducción de nuevos cursos de capacitación o en la mejora, actualización o suplementar los materiales de formación y de investigación en que la calidad y la Eficacia de los conocimientos y la experiencia puedes ser mejorado.

El simulador de ejercicios podrían utilizarse en la medida de lo razonable para cuantificar:

— carga de trabajo, la fatiga,
— niveles de estrés
— y el tiempo disponible para el cuidado.

Parámetros que deben cuantificarse se incluyen el número de operaciones realizadas y el tiempo utilizado en diferentes tareas.

Malentendidos (en la interacción hombre-máquina, así como en humanos, la comunicación humana), la pérdida de conocimiento de la situación y errónea planificación y ejecución será identificado como ocurren servirán de base para revelar los más importantes factores de riesgo e identificar los peligros. Además de los ejercicios simulador (I.M.O., Model Course 2.07, 2002; Kluj, 1997) permitir a los alumnos a familiarizarse con la instrumentación y los controles utilizados en las salas de máquinas de buques mercantes modernos, así como desarrollar la capacidad de convertirse en experto en la digitalización de las fallas que pueden ocurrir durante la operación de la planta.

Es bien sabido que uno de la mayoría de los sistemas críticos para el funcionamiento normal de los buques es el funcionamiento eficaz sin el mal funcionamiento de electro generadores. El uso cuidadoso de los grupos electrógenos en combinación con la distribución equitativa y el mantenimiento, utilizando listas de control adecuados (Kluj, 1999), puede conducir a la aparición de una disminución total de apagón. En virtud del lamentable condiciones un apagón puede poner en peligro la seguridad del buque, lo que a tierra o colisión. Un apagón no planificado, por lo tanto, debe ser considerada como una situación de emergencia y se trata de igual manera.

Con este fin, la influencia de vital subsistemas (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999), como gobernador, sistema de agua de mar, agua de refrigeración de aceite de lubricación, inicie el aire, la carga de turbo, el aire fresco y fuel en el normal funcionamiento de los generadores diesel, el electro, Ha sido estudiada.

Un intento de examinar los casos de mal funcionamiento básico de los generadores diesel, el electro y sobre todo la forma en que se podrían evitarse se ha hecho. En este documento se analizan algunas de las fallas de dichos sistemas y proporciona una visión de las diversas cuestiones técnicas relacionadas con la aplicación y el mantenimiento de los sistemas de energía eléctrica para aplicaciones marinas.

CONCLUSIONES

Estos experimentos forman parte de un concepto más amplio de trabajo (Gourgoulis et al., 2004) respecto de la utilización del simulador de motor que simula una dinámica en tiempo real computarizado de velocidad lenta de propulsión principal motor diesel turbo de la incorporación de una caldera de calor residual de vapor, un turbo generador y un eje generador.

A fin de evitar disfunciones que influyen en el funcionamiento normal de los generadores diesel, el electro durante el goteo, diariamente, el operador deberá comprobar el filtro de aceite diesel generador diesel, la bomba de aceite lubricante, el agua de mar el control de la temperatura, la resistencia al flujo de agua dulce, el Bomba de agua dulce, los subsistemas de la carga de turbo de aire fresco y el flujo de agua de refrigeración de inicio compresor de aire. Por lo tanto, la observación de todas las fallas producidas se deducía que la culpa es más peligroso mal funcionamiento M01 'Sucio filtro de aceite diesel generador diesel y de la culpa era menos peligroso mal funcionamiento M04' desgaste de la bomba de agua dulce generador diesel'.

La familiarización de los estudiantes con los sistemas eléctricos a bordo de los buques o equipos combinados con posibles fallas demostrado que los estudiantes tienen la oportunidad de desarrollar habilidades operacionales, para combinar con simulaciones multimedia de técnicas como animación, gráficos, imágenes, sonido, etc., para desarrollar y mejorar los conocimientos de idiomas Inglés De los buques de personal para hacer más corto el proceso de aprendizaje con el simultáneo aumento de la calidad y para que el proceso de evaluación de los alumnos mucho más eficaz.