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TROUBLESHOOTING OF MARINE STEAM TURBO ELECTRO GENERATORS USING ENGINE CONTROL ROOM SIMULATOR

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Abstrac

The aim of the present study is to examine the daily operation of steam - turbo engine driven electro generators used in maritime engineering for the auxiliary electrical power supply system of ship on real time operation and under malfunctions. On the ship, the preferred mode of operation is with shaft generator as base generator, the turbo generator as an auxiliary generator and with diesel generators in auto operation as stand by generators. Turbo generator modelled as high speed turbine with all vital subsystems such as rpm governor, lubrication oil and steam system with condenser. The research study attempts to make failure analysis and besides to provide solutions for real operating problems. The use of simulator under abnormal conditions helps the instructor and students to understand better the process while at the same time contributes significantly to the development of team spirit and enhances mutual respect and cooperation among to many job functions in the plant.

Key words: Engine Room Simulator, Turbo Generator, Malfunctions, Human factor

INTRODUCTION

The International Maritime Organization (S.T.C.W., 1995) has a key role to play in the successful implementation of new technology at sea. In line, with current policies on risk management and human factors, it will be advisable to research the full

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long-term effects of the introduction of each new system on the whole working environment, taking into account parameters such as the system design, maintenance, reliability and training. Besides, on board technology must be friendly, must leave humans in control and must not isolate the user from the outside environment.

One of the main purposes of computer simulation is to imitate the operations of real life systems or processes. The advent of bridge and engine room simulators and their use as modern research tools, now, allows us to test new technology before implementing it on board. With the help of instructors (IMO Model Course 6.09, 2001; IMO Model Course 2.07, 2002), it is possible to simulate conditions five or ten years ahead and measure the effectiveness of a fully implemented system, before committing the industry to a particular path. This is particularly important when training young people to meet future challenges. Training is costly and is made much easier and cheaper if systems have common human-machine interfaces and besides the main advantage of such simulations is that operational scenarios can be tested and evaluated without the need or use of actual experimentation. Today many maritime trainings centres apply engine room simulators in their didactic process.

Benefits of student by the incorporation of engine room simulator into a well focused marine training course are the next: technical knowledge by associating with his peers and absorbing the technical matter presented, the motivation of knowing that students – colleagues are interested in the same subject matter, the personal satisfaction of realizing that his knowledge are on par with those of others, personal acquaintances with serious minded instructors, state of the art solutions to problems where such solutions are not yet published and inspiration to enrol in and attend special courses accumulating continuing education units. Human hazards become less probable with adequate hands-on training, education, proper manning levels and timely and appropriate change management.

Simulator exercises (Kluj, 1999; Gourgoulis et al., 2004; Gourgoulis et al., 2008) could be used as far as practically reasonable to quantify work load, fatigue, stress levels and available time for watch out, decision and planning under conditions of continuously troubleshooting. Also, it must be noted that STCW 95 Convention (S.T.C.W., 1995) strongly recommends the application of engine room simulators in the teaching process. The application of simulators in the professional training of marine engineering is a mandatory requirement as determined by the standards of training, certification and watch keeping, which is an international convention for seafarers. The main objective of convention is to set a minimum level of specialized knowledge and qualification between seafarers.

The careful use of steam turbo generator, the avoidance of water strike in combination with the periodical maintenance, using suitable checklists, can lead to decreased consumption in cases that the demand of power are not extremely high. For this purpose the influence of vital subsystems such as such as rpm governor, throttle steam valve, lubrication oil and steam system with condenser on the normal operation of steam turbo electro generators have been studied.

An attempt to examine the basic malfunctions of steam driven turbo 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.

These experiments form part of a larger work (Gourgoulis et al., 2004; Gourgoulis et al., 2008) 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.

LIST OF SYMBOLS

TG	Turbo Generator
ALxx	Alarm xx
Mxx	Malfunction xx
LO	Lubrication oil

DESCRIPTION OF SIMULATOR

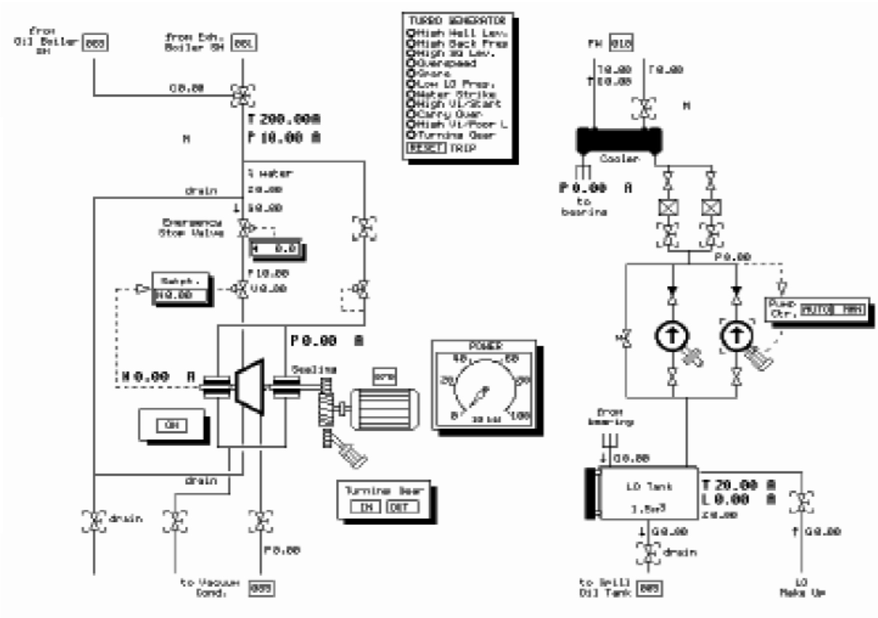
The engine room simulator plant at Merchant Marine Academy of Makedonia was established in 2002 and was designed, implemented and integrated by Kongsberg Nor control Simulation (Kongsberg Nor control, PPT2000-MC90-III, 1999).

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. 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: proposal phase, data collection and implementation, simulation and data recording, analysis and 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.

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. Turbo generator '*TG*' is an auxiliary generator and with diesel generators in auto operation as stand by generators. *TG* is modelled as high speed turbine with all vital subsystems such as rpm governor, lubrication oil and steam system with condenser [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. The turbine is modelled with torque dependent on steam flow, inlet steam pressure/temperature and condenser vacuum. *TG* is fed with superheated steam from the exhaust boiler. The exhaust fire boiler produces steam of approximately 290°C.

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, *TG* as an auxiliary generator and with two diesel generators in auto as stand by generators. Whenever, possible the *TG* should be prepared and connected and put to auto mode. In this case, the *TG* control must be changed from maximum load to frequency control mode. In auto mode it will be loaded according to available steam pressure. The recommended priority setting is priority 1 for the shaft generator, priority 2/3 for diesel generator 1 and 2. If only the shaft generator and turbo generator are connected there is no difference between operations in equal or optimal mode.



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

Figure 1: Steam engine driven TG.

In any case, *TG* will take as much power as possible. The *TG* throttle valve is limited to a value sufficient for keeping it connected at minimum steam pressure and close to zero power. The steam pressure must be higher than 9 bar and the steam throttle valve more than 15% lower than limiting value. *TG* can never become slave generator. This is taken care of by the power chief. *TG* has its own logic which means the turbo generator does not take any notice of the different load limits in the different load sharing modes. This is because of the fact that the most economical way to run *TG* is running at full load all the time. Before start of turbo generator vacuum must be established and the condenser must be drained.

Table 1 displays the alarms of steam *TG* (Kongsberg Nor control, PPT2000-MC90-III, 1999). Alarms of *TG* are divided into two types: high and low level alarms. *AL01* – *AL07*, rotor displacement (drain water strike or carry over water strike) and *AL10* give a trip signal for the safety protection of turbo generator.

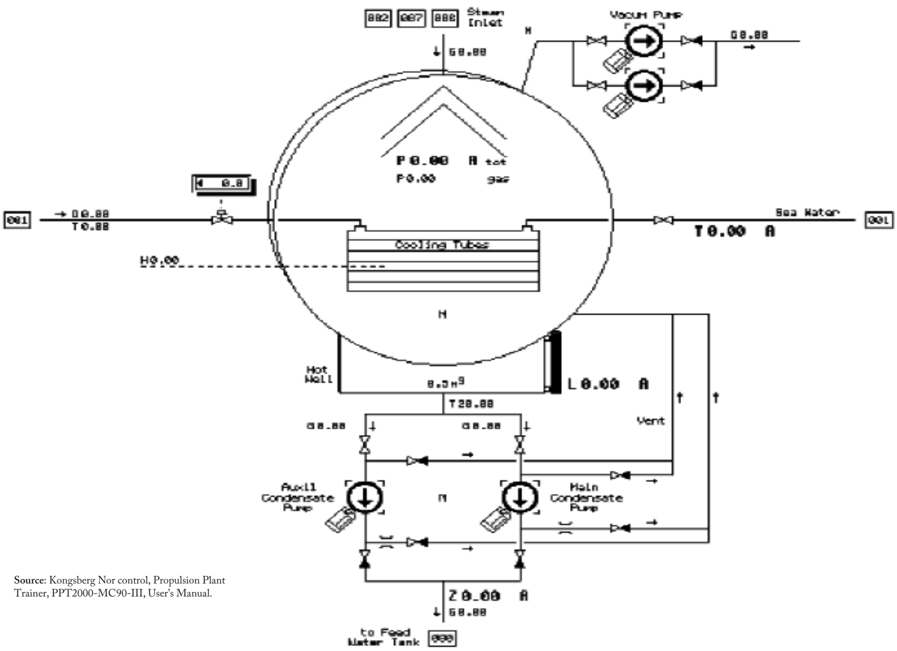
Table 1: Alarms (high-low level) of TG.

HIGH	*AL01*	Condenser hot well water level
	AL02	Condenser pressure (low vacuum)
	AL03	Steam generator water level
	AL04	*TG* over speed
	AL05	Stator temperature
	AL06	Vibration (cold start)
	AL07	Vibration (poor lubrication)
	AL08	*LO* tank temperature
	AL09	Lubrication oil tank level
LOW	*AL10*	*LO* pressure inlet bearings
	AL11	Steam inlet temperature *TG*
	AL12	Steam inlet pressure *TG*
	AL13	Sealing steam pressure

OBSERVATION PLAN

In the examined scenario the ship was running in open sea following the mode '*Full 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 94.4% and the main engine speed command was 74 *rpm*. The pitch was fixed and for the electrical power supply shaft and *TG* were in operation.

The turbine (Kongsberg Nor control, PPT2000-MC90-III, 1999) is modelled realistically with torque dependent on steam flow, inlet steam pressure - temperature and condenser vacuum. The throttle valve is controlled by a speed governor. The speed can be remotely adjusted by lower / raise signals from the electric switchboard. Governor of *TG* was a proportional – intergraded (PI) controller with compressed lever (P) and compensating valve (I) to be adjusted to 14.0 (P) and 0.9 sec (I) respectively. The set point of speed was 6464 rpm and the speed drop of turbo generator



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

Figure 2: Steam condenser.

was 50%. Before start of *TG* vacuum has been established and the condenser has been drained using the vacuum pump and main condensate respectively [Fig. 2, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. The required lubrication and freshwater systems for the cooling of *TG* have been prepared [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)].

Several faults have been introduced in order to demonstrate cascading of abnormal conditions that influence the operation of steam *TG*. From Table 2 it can be observed that *M01-M08* malfunctions are related with the operation and subsystems of *TG* (Fig. 1) and the rest *M10-M20* are related with the correct per formation of steam condenser (Fig. 2). Examining the possible malfunctions of *TG* and steam condenser it can be deduced that *M08* (*LO* filter 2, Fig. 1) and *M12-M13* (Auxiliary condensate pump, Fig. 2) were not possible to be activated due to the fact *LO* filter 1 and main condensate pump respectively were in operation. In addition, the next malfunctions (*M07*, *M11*, *M13*, *M15* and *M19*) have not the possibility to be ramped and the starting malfunction point is 100%. The other malfunctions of Table 2 might be ramped from the initial set point 100% to the specified malfunction set point. Faults could be edited on line and for each inserted malfunction the observation time was specified to be 20 minutes in order to have a stable factor for evaluation. Each malfunction (Kongsberg Nor control, PPT2000-MC90-III, 1999) is activated (100%) immediately with the running of scenario.

Table 2: Malfunctions of TG – Steam Condenser.

TG	*AL01*	Condenser hot well water level
	M01	*TG* speed controller gain high
	M02	Turbine efficiency low
	M03	*TG* mechanical *LO* pump wear
	M04	*TG LO* cooler dirty
	M05	*TG LO* filter 1 dirty
	M06	*TG LO* system water inlet leakage
	M07	*TG* gland steam controller fail
	M08	*TG LO* filter 2 dirty
LOWSTEAM CONDENSER	*M10*	Main condensate pump wear
	M11	Main condensate pump motor failure
	M12	Auxiliary condensate pump wear
	M13	Auxiliary condensate pump motor failure
	M14	Vacuum pump 1 wear
	M15	Vacuum pump 1 motor failure
	M16	Vacuum pump 2 wear
	M17	Vacuum pump 2 motor failure
	M18	Vacuum condenser air leakage
	M19	Vacuum condenser dirty
	M20	Vacuum condenser sea water leakage

Activating *M01*, *M02*, *M04*, *M06*, *M08* the behaviour of systems was always the same in the observation period of 20 minutes. In 11:37 minutes from the activation of particular malfunctions one alarm was only presented (Fig. 3). As can be seen from figure 3 the caused alarm 'High aft bilge well level > 0.5m' is not vital for the correct operation of *TG*, there is plenty of time for the re-establishment of damage and for the above reasons malfunctions of Fig. 3 were not reprogrammed at lower percentage of damage.

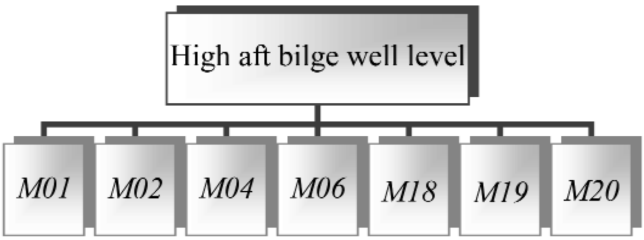
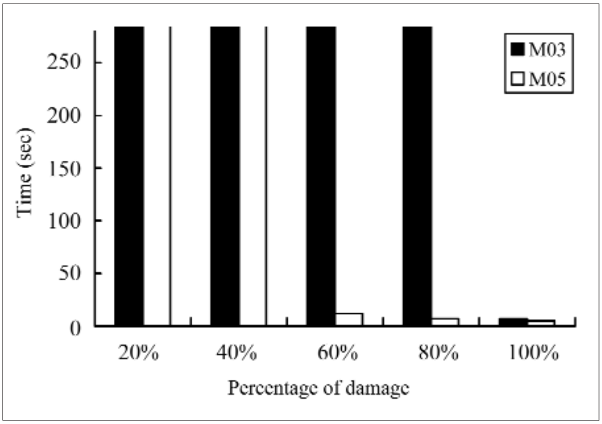


Figure 3: Alarm of malfunctions.

For the demonstration of the *TG* driven alarm *AL10* '*LO* pressure inlet bearings', *M03* '*TG* mechanical *LO* pump wear' was activated after the running of scenario. The lowest limit of pressure for the correct lubrication of inlet bearings is 1,5 *bar*. Figure 4 shows the appearance time of alarm *AL10* at the different stages of produced fault. From this figure it can be seen that the increase of damage over 80% does not give to personnel the adequate time for the quick re-establishment of damage. For the repair of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] was activated the electrical *LO* pump and was deactivated the mechanical *LO* pump. Besides, *AL10* can be presented by the activation of *M05* '*TG LO* filter 1 dirty'. From figure 4 it can be seen that the increase of damage over 40% leads in the activation of *AL10* in 12 *sec* for the avoidance of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] the engineer who is doing watch keeping must inspect periodically the cleanness of *TG LO* filters. The cleanness of *TG LO* filters is not only vital for the operation of *TG* but for the total operation of ship. It was observed that for damages of *M05* over 80% the shutdown of main engine was presented in 6 minutes after the running of scenario.

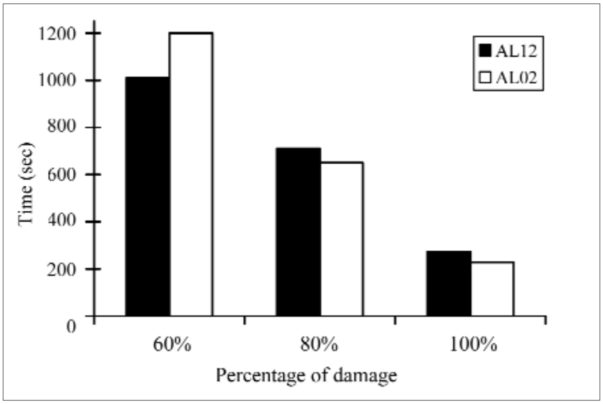
Figure 4: Appearance time of AL10.



■ *M03, TG* mechanical *LO* pump wear
□ *M05, TG LO* filter 1 dirty

For the demonstration of the *TG* driven alarm *AL01* 'Condenser hot well water level', *M10* 'Main condensate pump wear' was activated after the running of scenario. The highest limit of condenser hot well water level is 650 *mm*. It can be observed that the decrease of damage under 80% does not display *AL01*. The careful maintenance of main or auxiliary condensate pump can lead in the avoidance of difficult situations. Besides, for the demonstration of the *TG* driven alarm *AL13* 'Sealing steam pressure' [6], *M07* '*TG* gland steam controller fail' was activated after the running of scenario. *M07* has not the possibility to be ramped and the percentage of damage is 100%.The lowest limit of sealing steam pressure is 0,1 *bar*. It was observed that *AL13* was present in 6 sec after the running of scenario. For the avoidance of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] the engineer who is doing watch keeping must inspect periodically the correct adjustment of *TG* gland steam controller.

Figure 5: Average appearance time of AL12 and AL02.



■ *AL12,* Steam inlet pressure *TG*
□ *AL02,* Condenser pressure (low vacuum)

For the demonstration of the *TG* driven alarm *AL12* 'Steam inlet pressure *TG*' a different combination of malfunctions could be used. Six malfunctions (*M03*, *M05*, *M07*, *M10* and *M16*) were able to cause *AL12*. In the same way, for the demonstration of the *TG* driven alarm *AL02* 'Condenser pressure (low vacuum)' three malfunctions (*M16* and *M17*) could be programmed. The lowest limit of steam inlet pressure to *TG* is 7,0 *bar* and the highest limit of condenser pressure is 0,2 *bar*. Figure 5 shows the average appearance time of alarm *AL12* and *AL02* at the different stages of produced faults. From this figure it can be seen that the increase of damage over 80% does not give to personnel the adequate time for the quick re-establishment of damage. Finally it can be observed that for damages of *M16* over 60% the shutdown of main engine was presented in 4 minutes after the running of scenario.

CONCLUSIONS

Human factors are related to crew competence in terms of decision-making, communication, operating skills. Human error is an existence parameter that often proves almost impossible to remove from the maritime safety formula. Thus, the human failures can be avoided by different ways: firstly by improving the management and crew organisation; then by doing a careful selection of the crew and thirdly by increasing the training quality and quantity, both for ordinary and emergency situations. The use of marine simulators would improve both the training and the selection.

In open sea, *TG* is mainly an auxiliary generator and for the avoidance of malfunctions that influence the normal operation of *TG* during the drip, daily, officer in charge of an engineering watch keeping (IMO Model course 7.04, 1999; IMO Model course 7.02, 1999) must check the cleanness of *TG LO* filters, the correct function of lubricant mechanical or electrical oil pump, the effective operation of auxiliary or main condensate pump, the correct adjustment of *TG* gland steam controller and the total function of steam condenser. Examining all produced faults it was deduced that the most dangerous faults were *M05* '*TG LO* filter 1 dirty' and

M16 'Vacuum pump 2 wear'. It was observed that for damages of *M05* and *M16* over 80% and 60% respectively the shutdown of main engine was presented in very short period after the running of scenario.

In order to avoid trip signal of *TG* breaker due to water strike, rotor displacement and vibration is recommended *TG* to start without the presence of water in the line of steam, the increase of speed of *TG* to become very slow, the emergency stop valve to open very late keeping the speed of *TG* at low limits in case of cold *TG*. The *TG* is protected by a separate safety system and trip signal is given on the following conditions: low *LO* pressure (by the activation of *M05*) high back pressure (by the activation of *M14*, *M16* and *M17*).

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REFERENCES

Conference Papers

Gourgoulis, D. E.; Vouvalidis, X. A.; Schinas, C. A.; Gotzamanis, G. P. (2004): 'Shutdown and slow down action of engine used in marine engineering.' *Proccedings of 4th International Congree on Maritime Technological Innovations and Research*, Barcelona, pp 351-362.

Kluj, S. (1997): 'The Computer Aided Assessment for Engine Room Simulator', *Proceedings of 3rd International Conference on Engine Room Simulators*, Svendborg,.

Journal articles

Gourgoulis, D. E.; Yakinthos, C. G. (2008): 'Behaviour of marine electro generators under abnormal conditions using engine control room simulator' *Journal of Maritime Research*, 2008, pp 23-38, Volume 5, No. 2, Spain.

Manuals

Kongsberg Nor control (1999): Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual.

Standards

STCW (1995): *International Convention on Standards of Training, Certification and Watch keeping for Seafarers*, (IMO Sales No. 938), and 1997 Amendments to STCW 95 (IMO Sales No. 945).

IMO (2002): International Maritime Organization, Model course 2.07, Engine room simulator.

IMO (2001): International Maritime Organization, Model course 6.09, Training course for instructors.

IMO (1999): International Maritime Organization, Model course 7.04, Officer in charge of an engineering watch.

IMO (1999): International Maritime Organization, Model course 7.02, Chief engineer officer and second engineer officer.

LOCALIZACIÓN DE AVERÍAS EN LOS ELECTRO TURBO DE VAPOR DE LOS GENERADORES MARINOS USANDO EL SIMULADOR DE LA SALA DE MÁQUINAS

Resumen

La puntería del actual estudio es examinar la operación diaria del vapor - generadores accionados por el motor de turbo electro usados en la ingeniería marítima para el sistema de fuente auxiliar de la corriente eléctrica de nave en la operación en tiempo real y bajo malfuncionamientos. En la nave, el modo de operación preferido está con el generador de eje como generador bajo, el generador de turbo como generador auxiliar y con los generadores diesel en la operación auto como hace una pausa los generadores. Generador de Turbo modelado como turbina de alta velocidad con todos los subsistemas vitales tales como gobernador de la rpm, aceite de lubricación y sistema del vapor con el condensador. El estudio de la investigación intenta hacer análisis de la falta y además de para proporcionar las soluciones para los problemas verdaderos del funcionamiento. El uso del simulador bajo condiciones anormales ayuda al instructor y a los estudiantes a entender mejor el proceso mientras que al mismo tiempo contribuye perceptiblemente al desarrollo del alcohol de equipo y refuerza respecto y la cooperación mutuos entre a muchas funciones de trabajo en la planta.

INTRODUCCIÓN

La organización marítima internacional (S.T.C.W., 1995) tiene un papel dominante a jugar en la puesta en práctica acertada de la nueva tecnología en el mar. En línea, con políticas actuales en la gestión de riesgos y factores humanos, será recomendable investigar los efectos de largo plazo completos de la introducción de cada nuevo ambiente de trabajo del sistema en general, considerando parámetros tales como el diseño de sistema, mantenimiento, confiabilidad y el entrenamiento. Además, a bordo tecnología debe ser amistoso, debe dejar a seres humanos en control y no debe aislar al usuario del ambiente exterior.

Uno de los propósitos principales de la simulación de computadora es imitar las operaciones de los sistemas o de los procesos de la vida real. El advenimiento de los simuladores del sitio del puente y de motor y de su uso como herramientas modernas de la investigación, ahora, permite que probemos nueva tecnología antes de ejecutar de ella a bordo. Con la ayuda de los instructores (IMO Model Course 6.09, 2001; IMO Model Course 2.07, 2002), es posible simular condiciones cinco o diez años a continuación y medir la eficacia de un sistema completamente ejecutado, antes de confiar la industria a una trayectoria particular. Esto es particularmente importante al entrenar a gente joven hacer frente a desafíos del futuro. El entrenamiento es costoso y se hace mucho más fácil y más barato si los sistemas tienen interfaces persona-máquina comunes y además de la ventaja principal de tales simulaciones es que los panoramas operacionales se pueden probar y evaluar sin la necesidad o el uso de la experimentación real. Muchos centros de entrenamientos marítimos aplican hoy los simuladores del sitio de motor en su proceso didáctico.

Las ventajas del estudiante por la incorporación del simulador del sitio de motor en un curso de aprendizaje marina enfocado pozo son las siguientes: el conocimiento técnico asociándose a sus pares y absorbiendo la materia técnica presentó, la motivación de saber que los estudiantes - los colegas están interesados en el mismo tema, la satisfacción personal de realizar que su conocimiento está junto con los de otros, conocidos personales con los instructores importados serios, soluciones avanzadas a los problemas donde tales soluciones todavía no se publican e inspiración para alistar adentro y para atender a los cursos especiales que acumulan unidades de la formación permanente. Los peligros humanos llegan a ser menos probables con el entrenamiento con manos adecuado, la educación, los personal apropiados y la gerencia oportuna y apropiada del cambio.

Los ejercicios del simulador (Kluj, 1999; Gourgoulis et al., 2004; Gourgoulis et al., 2008) se podrían utilizar hasta prácticamente razonable para cuantificar la cantidad de trabajo, la fatiga, niveles de tensión y la hora disponible para tienen cuidado, decisión y planeamiento bajo condiciones continuamente de la localización de averías. También, debe ser observado que la convención de la STCW 95 (S.T.C.W., 1995) recomienda fuertemente el uso de los simuladores del sitio de motor en el proceso de enseñanza. El uso de simuladores en el entrenamiento profesional de la arquitectura naval es un requisito obligatorio según lo determinado por los estándares del entrenamiento, de la certificación y del reloj guardando, que es una convención internacional para los navegantes. El objetivo principal de la convención es fijar un nivel mínimo de conocimiento y de calificación especializados entre los navegantes.

El uso cuidadoso del generador de turbo del vapor, la evitación de la huelga del agua conjuntamente con el mantenimiento periódico, usando listas de comprobación convenientes, puede llevar a la consumición disminuida en casos que la demanda de la energía no es extremadamente alta. Con este fin la influencia de subsistemas vitales tales como por ejemplo el gobernador de la rpm, la válvula de vapor de la válvula reguladora, el aceite de lubricación y el sistema del vapor con el condensador en la operación normal generadores de turbo del vapor de los electro se ha estudiado.

Se ha hecho una tentativa de examinar los malfuncionamientos básicos de los electro generadores conducidos vapor de turbo y especialmente cómo son se podría evitar. Este papel discute algunas de las averías de tales sistemas y proporciona una penetración en las varias ediciones técnicas asociadas al uso y al mantenimiento de los sistemas eléctricos eléctricos para los usos marinas.

Estos experimentos forman la parte de un trabajo más grande (Gourgoulis et al., 2004; Gourgoulis et al., 2008) referente al uso del simulador del motor que simula un motor diesel turbocharged automatizado tiempo real dinámico de la propulsión principal despacio que incorpora una caldera de vapor del calor residual, un generador de turbo y un generador de eje.

CONCLUSIONES

Los factores humanos se relacionan con la capacidad del equipo en términos de toma de decisión, comunicación, funcionando habilidades. El error humano es un parámetro de la existencia que prueba a menudo casi imposible quitar de la fórmula de la seguridad marítima. Así, las faltas humanas se pueden evitar por las maneras diferentes: en primer lugar mejorando la organización de la gerencia y del equipo; entonces haciendo una selección cuidadosa del equipo y en tercer lugar aumentando la calidad y la cantidad del entrenamiento, para el ordinario y las situaciones de emergencia. El uso de simuladores marinas mejoraría el entrenamiento y la selección.

En el mar abierto, el *TG* es principalmente un generador auxiliar y para la evitación de los malfuncionamientos que influencian la operación normal de *TG* durante el goteo, diario, oficial a cargo de un reloj de ingeniería que guarda (IMO Model course 7.04, 1999; IMO Model course 7.02, 1999) deben comprobar la limpieza de los filtros del TG LO, la función correcta de la bomba mecánica o eléctrica del lubricante de aceite, la operación eficaz de la bomba condensada auxiliar o principal, el ajuste correcto del regulador del vapor de la glándula del *TG* y la función total del condensador del vapor.

Para evitar la señal del viaje del triturador del *TG* debida regar huelga, la dislocación del rotor y la vibración es *TG* recomendado a comenzar sin la presencia de agua en la línea de vapor, el aumento de la velocidad del *TG* a llegar a ser muy lento, la válvula de parada de emergencia para abrir muy tarde la custodia de la velocidad del *TG* en los límites bajos en caso del *TG* frío. El *TG* es protegido por un sistema de seguridad separado y la señal del viaje se da en las condiciones siguientes: presión trasera baja de la presión de *LO* (por la activación de *M05*) alta (por la activación de *M14*, de *M16* y de *M17*).