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Simulator Training beyond the boundaries of Engine Room Watch-keeping

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Abstract: Traditionally and historically, engine room simulators are employed by Maritime Education and Training (MET) institutes to educate trainees to face real life machinery space situations commonly known as watch-keeping which enable safe operation of the ship. In addition, the trainees can be prepared to face the emergency situations with suitable exercises. International Maritime Organization (IMO) convention on Standards of Training, Certification and Watch-keeping (STCW) also recommends approved simulators for assessment of competency and demonstration of continued proficiency in certain areas. [1] Essentially, the scope of engine room simulator training was restricted to training engine room watch-keeping and assessment.

The capabilities of modern simulators in maritime training and education are gaining importance in recent times due to its unique features in providing integrated learning to students. Marine engineering, comprising of several facets of engineering such as Mechanical, Electrical and Electronics, Control systems, Heating, Ventilation and Air Conditioning (HVAC), finds simulators playing a vital role that surpasses any other medium of instruction. In the hands of dedicated and creative simulator instructors the engine simulators can provide another dimension of integrated learning. Simulators can be used to provide the theoretical foundation to most of the engineering concepts in various branches of engineering mentioned above. For example, the concept of reactive power in electrical engineering and its effect on the distribution system at various settings can be best demonstrated to students with advanced simulation exercises. This goes beyond the limits of traditional simulator exercise regime.

This paper analyses how the engine room simulator technology can be utilized to teach theoretical engineering concepts with carefully created simulator exercises that display various trends and relevant quizzes. The exercises do not entirely reflect engine room watchkeeping but augment theoretical engineering concepts with practicals, which may not be possible to do in a normal classroom situation or in a training ship scenario without a substantial cost / risk. Further the quizzes inserted in suitable instances within the exercise enable the student an integrated approach to purposeful learning. The quizzes further provide the instructor an authentic assessment scheme of individual student's learning and grasp of the theoretical concepts. The paper also aims to indicate that this methodology will provide a pathway for training future autonomous ship operators.

Keywords: emergency preparedness, autonomous shipping, future maritime training

Introduction

Engine Room Simulators (ERS) are essentially dedicated to train and assess engineers in watch-keeping duties. The manufacturers of simulator algorithms create malfunctions which when injected into scenarios make disturbances in running parameters of the machinery which are identical to the real life situations. The trainees are expected to respond to the situations and rectify the faults or initiate corrective action as specified to reinstate normal running conditions.

The ERS manufacturers like Kongsberg clearly display the intentions of creating these malfunctions in their product brochure under the heading 'Training Philosophy' as follows: "Simulator training has over the last years proved to be an effective training method when training engineers, especially where an error of judgment can endanger life, environment, and property. A dynamic real-time computerised simulator can compress years of experience into a few weeks and give knowledge of the dynamic and interactive processes typical for a real engine room. Proper simulator training will reduce accidents and improve efficiency and give the engineers the necessary experience and confidence in their job-situation." [3]

Although Kongsberg Training Philosophy states: "A simulator will give an easy introduction to background theories through the realistic operation of the simulator" the real exploitation of the simulator for theoretical training lies in the hands of a dedicated ERS instructor. Background theories emphasize and consolidate engineering concepts which is essential for competence training.

Example # 1 - Generator load sharing and governor droop

Comprehending the effect of governor speed droop for diesel engines as prime movers, may be quite challenging even for the final year students in the STCW management level competence training, when it comes to load sharing between two or more generators. To demonstrate that the generator with less governor speed droop take more load in a load sharing situation, two Diesel Generators (DG # 1 and DG # 2) are run to share the total load while maintaining the governor speed droop at 60% (default value) in each generator. During the investigation the students must keep the power management system switched off by changing over all generators to manual mode. Next the Bow thruster is started as the controlling device for the load for the generators and the pitch kept at a low value. The pitch is controlled only when the generator loads need to be varied. It is not considered as a controlling variable in the research.

We use the 'Trend Group Directory' in the simulator to record the variation of the following parameters:

1. Diesel Generator # 1 kW load (Red)
2. Diesel Generator # 2 kW load (Beige)
3. Diesel Generator # 1 droop setting (Green)
4. Diesel Generator # 2 droop setting (Purple) – which is the controlled variable

Both DGs are identical in operational characteristics under same droop. Total load capacity for each generator is 900 kW.

Starting with equal load sharing of a total of approximately 1050 kW of active power we reduced droop in DG # 2 from 60% (default value) to 40% in 5% steps. DG # 2 step reductions are shown in Purple. For each step reduction of droop in DG # 2, DG # 1 dropped its kW load while it was gained by DG # 2. Students can clearly observe that the Generator with less droop, i.e. DG # 2 takes more kW load than the Generator with larger droop; in this instance DG # 1 where we did not change the droop and maintained it at 60%.

The Figure 1 below shows how load is gained by DG # 2 at each step reduction of its droop. The load gained by the DG #2 is the mirror image of the load reduced from the DG # 1

In the second demonstration we do a similar variation of droop for DG # 1 while keeping Turbo Generator (TG) droop constant at 50%. Similar to the first one we start the exercise with the same total load of 1050 kW shared equally between the DG # 1 and TG. The difference from the first exercise is that the TG has a Droop setting of 50%. DG # 1 step reductions are shown in Green. As the DG # 1 Droop is reduced from 60% to 35% its kW load increases as shown by the red curve, while the TG load is dropped (Beige curve). Similar to the first exercise red curve is the mirror image of the beige.

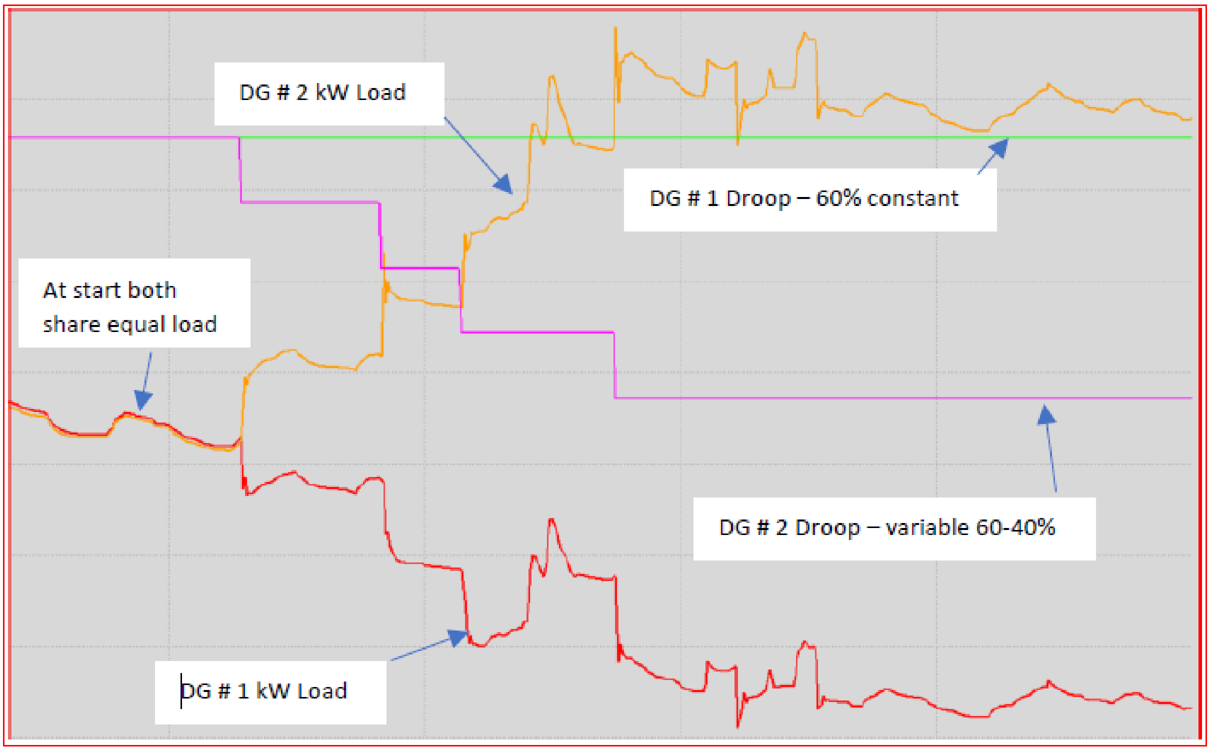

Figure 1. How variation in DG # 2 Droop affects both DG # 1 and DG # 2

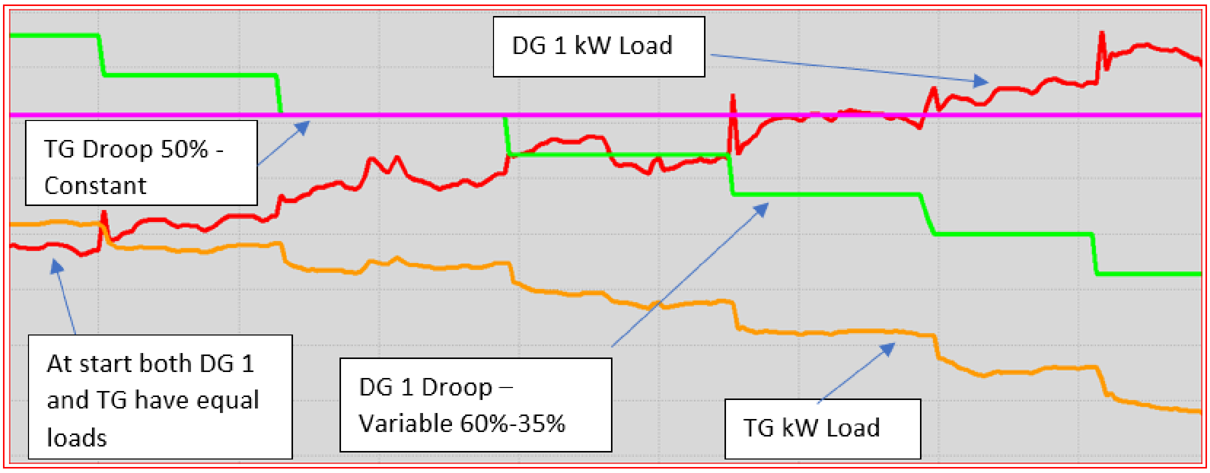

Figure 2. How variation in DG # 1 Droop affects both TG and DG # 1

This demonstration of how two generators running in parallel can further be extended to:

- One generator running with droop and the other with an 'isochronous' (zero droop) governor. In this demonstration we run DG #1 with 60% constant droop and DG # 2 with zero droop or isochronous governor.
- Finally, we run both DGs with isochronous governors. In both above situations we run the total load below 900 kW to prevent a blackout situation.

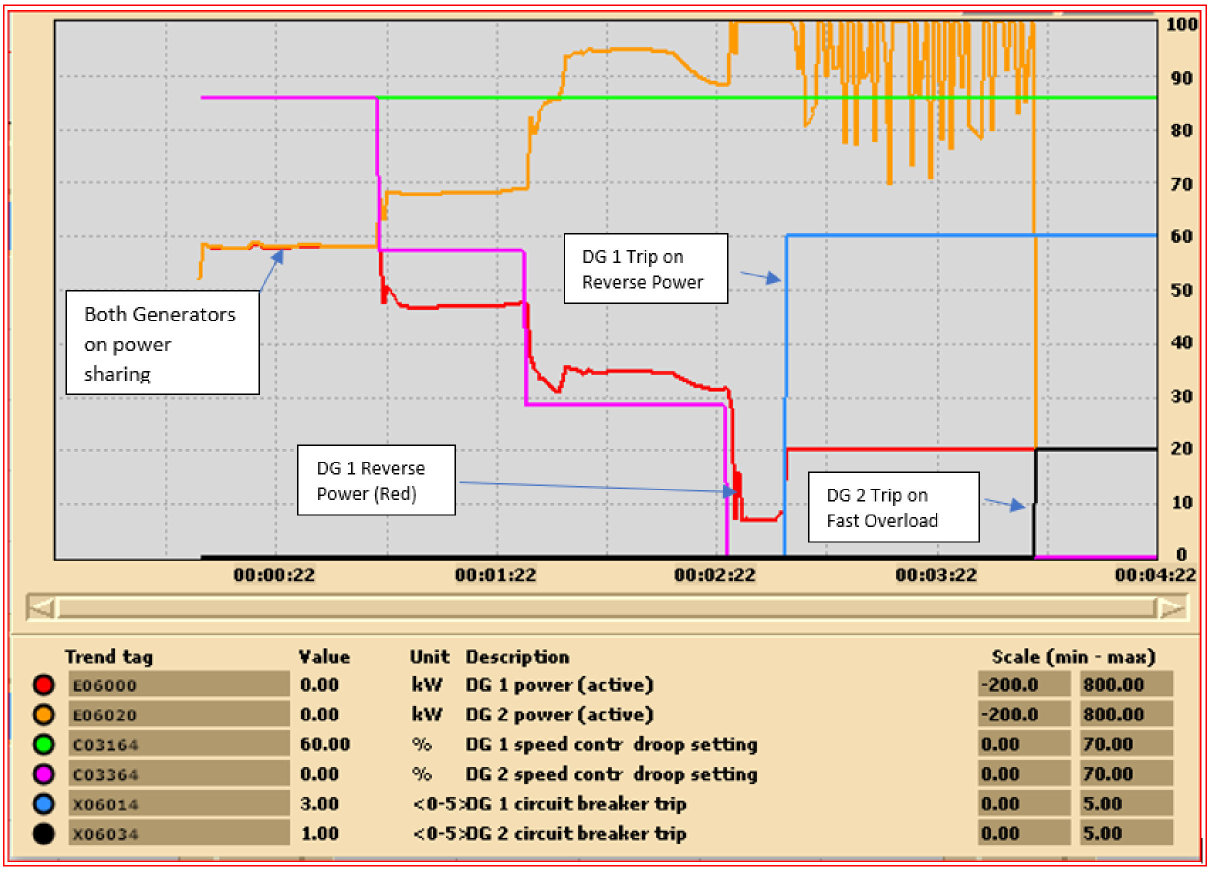

Figure 3. The results of running DG # 2 as Isochronous and DG # 1 as Droop.

Note the reduction in droop setting in DG # 2 from 60% to 0% in three steps of 20% each. When DG # 2 Droop setting (Purple) reaches zero, it behaves as an isochronous governor and takes the total load. As a result, DG # 1 goes into reverse power as it's ACB is still connected. Subsequently DG # 1 trips on 'Reverse Power Protection. Although the total load of the system is less than 900 kW. Soon after DG # 1 is tripped, the isochronous governor of DG # 2 is trying to cope up with load fluctuations and trips after 1 minute 7 seconds on 'Fast Overload', causing an inevitable black out situation.

Finally, it can be demonstrated that if we run both generators with isochronous governors, the system becomes very unstable as both generators are fighting to supply power to the system and eventually trip off one by one as in the previous demonstration. The first generator will trip on Reverse Power while the second will be on Fast Overload.

These simulator demonstrations make some concepts that would be very difficult to explain in a classroom setting quite feasible, eliminating demonstration with very expensive real equipment.

Example # 2 – Powerfactor correction with Synchronous Motor

In an AC distribution system power factor correction can be done by two methods:

a) Capacitor bank
b) Synchronous motor

The theory and practice involved with employing capacitors to correct power factor is quite straight forward. The inductive loads in a distribution system such as motors and transformers create a phase difference between the supply voltage and the current. This phase difference can be eliminated by introducing a suitable capacitor to the circuit that counter acts to make the phase difference to almost zero.

However, the synchronous motor method needs clarification for most students as the underlying principles need demonstration and clarification. The Shaft generator of Kongsberg MC-90-V simulator provides the reverse

operation of the Synchronous generator as a synchronous motor, which enables the students to understand the concepts of power factor correction by excitation control of the rotor. In a synchronous motor there are two rotating magnetic fields. The first is the stator rotating magnetic field which starts rotating in the airgap once the 3-phase supply is switched on. Once the rotor reaches the full speed it has no relative cutting by the stator rotating magnetic field and the first magnetic field has no effect on any other components. However, the second rotating magnetic field is due to the rotor coils which are supplied with a DC supply to create the rotor magnets. This second rotating magnetic field cuts the stator of the motor, which is stationary and induces a back e.m.f. in the stator. The magnitude and the phase angle of this. back e.m.f. depends on the excitation of the rotor. This back e.m.f. in turn can either make the Supply voltage and current to lag, lead or stay in-phase.
In the demonstration we start with the Full Ahead Loaded ship. The synchronous motor is now on "Power Take Off" (PTO) or Generator mode. First, we need to record the values of the following:

1. Propellor speed / Ship speed and Fuel economy
2. Generator stator current
3. Power produced by the shaft generator
4. Power factor as the Shaft Generator
5. Power factor of the Turbo Generator

Then we start the DG # 1 and share the load with TG so that we can run the Shaft Generator as a synchronous motor. We follow the steps given below to achieve "Power Take In" (PTI) or Synchronous motor which gives a boost to the shaft to improve the fuel economy of the main engine. By varying the excitation of the synchronous motor rotor, we change the system power factor. At the optimum Power Factor position, (1.000) we again record the values mentioned above to determine the effect of the synchronous motor running in PTI mode.

Item	Parameter	PTO (Generator Mode)	PTI (Motor Mode)
1	Propellor speed	74 RPM	74 RPM
2	Ship speed	15.37 Knots	15.37 Knots
3	Fuel economy	205.73 Kg/Nm	201.97 Kg/Nm
4	Power produced	350.9 kW	-537 kw
5	Power factor	0.783	-0.998
6	Power factor of TG / DG	0.91 / 0.92	0.78 / 0.85

Table 1: Parameters of the Shaft generator showing fuel economy of Main Engine in PTI Mode.

Power Factor correction

We can further vary the Excitation and observe the behavior of the Power factor of the motor along with the stator current to plot the Synchronous motor V-curves and inverted V-curves.

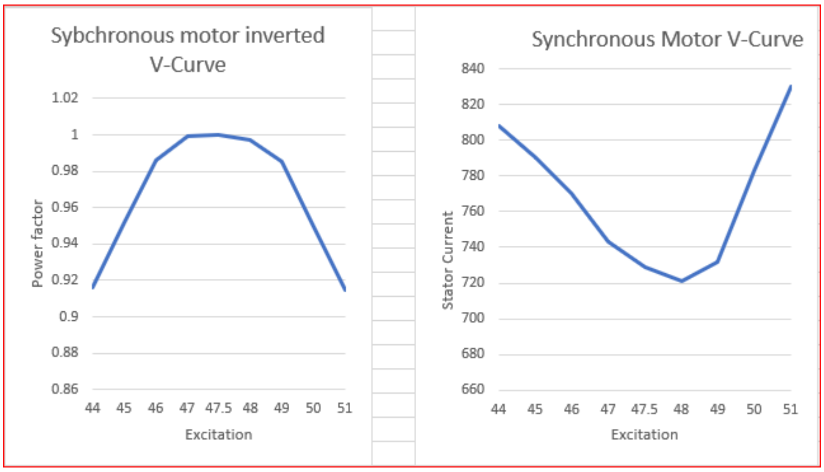

Figure 4: Variation of system power factor and Stator Current by varying Rotor Excitation.

Note that in the Table above fuel economy has improved, confirming that the shaft generator is now running as a motor giving extra power to the main engine.

The controlling of the power factor by varying rotor excitation is clearly observed and analyzed by the students with the evidence provided by the simulator. The evidence in the Table 1 above is to confirm that the motor in PTI mode enables saving of fuel as the synchronous motor delivers additional torque to the propeller shaft.

Further Examples

While the above examples prove that the engine room simulators can be used to augment theoretical training concepts by well prepared exercises, further examples involving tunning of controllers in the engine room can be added to this list. Tunning Proportional+ Integral + Derivative (PID) 3-Term controllers normally involve the following accepted methods:

1. Zeigler Nichols
2. Cohen Coon

Both above methods employ quarter wave damping which can be very explicitly interpreted by the 3-Term controllers in the engine simulator.
Additionally, we use exercises on Refrigeration for demonstration of common problems that cannot be done with real equipment.

Conclusions

Despite the troubles or events that are expressed by the simulator system are the same, the behavior carried out by the trainees are different based on their knowledge and skills. J. Rasmussen explains that the reading of the indicator needle of the flowmeters may be interpreted differently depending on the situation.[2] The difference in the normal condition as "signal", the trigger for the next action is as "sign", the difference under the understanding of the situation is as "symbol". Similarly, Endsley defines the difference in situational awareness as three levels: perception, comprehension, and prediction. [4]
In recent years, the ability of the engine room simulator is not limited to accident reproduction, and it seems that it is possible to acquire higher situational awareness with the intention of the instructor.
Although Engine Simulators are generally accepted as the best tools for operational training for marine engineers a new dimension of its capabilities has been discovered as interpreted by the examples in this paper, where theory is combined with practice to consolidate the learning.
The authors are convinced that further inroads can be made into this domain to explore what other possibilities exist to facilitate learning for marine engineers for future autonomous shipping.

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