Project- RV Gunnerus

TMR4335 - Marin teknikk 4 - Propulsjonssystemer, sikkerhet og miljø

(TMR4335- TMR4335 Marine Technology - Propulsion Systems, Safety, and Environment)

Due Date- Week 12, 8th November. Grade weight- 30% of final grade.

Objectives of the project

At its most basic, one of the main objectives of the project is to go on board a vessel and see real machinery and power systems and start to develop an understanding of how they actually work together, where they are placed on board the vessel, how they are maintained and how component reliability will affect a system.

- Mapping of the real components and arrangements on a vessel to the drawings of the system- understand that the documentation is not a physical representation of the system, it is a simplified schematic.
- Identify components and systems from drawing to real system.
- To develop an understanding of real marine machinery and power systems.
- To develop an understanding of reliability of marine machinery/power systems based on real system observations.
- Be able to describe a real power system on a vessel and conduct a basic analysis of power demand during short voyage.
- Use data to examine the characteristics of the machinery (engine specific fuel consumption and engine efficiency for different points of operation), electric power system (vessel power profile, power system efficiency, effect of load sharing, voltage/current/power on the switchboard).
- Handle a data-set and present findings in clear manner and elaborations of the understanding.
- Be able to analyse reliability, identify and evaluate failure modes for a machinery system, and on the basis of this analysis be able to propose relevant maintenance tasks at a general level.
- See relationships between a ship's operating patterns, reliability, maintenance and fuel consumption.

General information

Work on this task is carried out in groups, you will have a sign up on blackboard for your groups. The groups will work together when on board the Gunnerus and when writing their report. The report must be a **maximum of 25 pages, including all front matter**. Clear and consistent use of source references and referencing is expected.
Use template- Overleaf- Template Project NTNU
https://www.overleaf.com/latex/templates/template-project-ntnu/zjystqvqztpg

Evaluation and grading

The project work counts for **30% of the total grade** in the course.

- The written quality of the report itself counts 20%.
- Presentation of results, including figures, tables, forms, etc., counts 20%.
- The completion of calculations, handling the data and determine the required results count for 60%.

Introduction and procedure

The assignment is focused on a voyage on NTNU Research Vessel Gunnerus (RVG). During the voyage the vessel will leave harbour and sail to Munkholmen and back to harbour. During the voyage, some data from the engines will be logged using the onboard data acquisition system, which sends data to a server and can be accessed by a laptop. The vessel data – including machinery and power system – will be given just after the vessel visit.

During the voyage, the operating scenario of the power system may vary (manually or automatically by PMS), to meet the load demand (using either, 1, 2 or all three gensets) so called “load sharing”. The vessel can be operated in constant power or constant speed mode.

Machinery room: the installed power is 3 diesel generators (diesel engine + synchronous generator), rated at 450 kW each.

Switchboard: the 3 gensets are connected to a common AC switchboard at low voltage (also located beside the machinery room) which is rated at 440 V (this is RMS voltage). The AC switchboard supplies all the load including propulsion load, hotel load, and other onboard loads.

Propulsion system/thrusters/DP: 2 main electric thrusters, each rated at 500kW, and 1 tunnel thruster of 200kW (bow thruster). All the 3 thrusters are electric motors and are connected to the main AC switchboard. The thrusters are driven by variable speed drives (VSD), also known as frequency converters. These VSDs can dynamically control the motors and receive different setpoints, both for the speed and torque. On the vessel, the main propulsion thrusters (PM1 and PM2) are also indicated by "Port" and "Starboard (Stbd.)". Same notations are also used in the data recording, so would be easy to find them in the file which is a csv file with the following channels logged.

- Engine 1
- Engine speed-rpm
- Engine load-kW
- Fuel consumption-l/h
- Engine 2
- Engine speed-rpm
- Engine load-kW
- Fuel consumption-l/h
- Engine 3
- Engine speed-rpm
- Engine load-kW
- Fuel consumption-l/h
- hcx_port_mp (port side main propulsion thruster)
- RPMFeedback-%
- LoadFeedback- %
- hcx_stbd_mp (starboard side main propulsion thruster)
- RPMFeedback-%
- LoadFeedback- %

The base power for each main propulsion thruster is 500kW. To calculate the power that each main propulsion thruster is using from the logged data, the LoadFeedback percentage is multiplied with the base power of the thruster, this will give the power in KW that the thruster was using. You do not need the RPMFeedback.

Task 01

The objective of this task is for you to spend some time trying to represent the real system that you have seen on board in a diagram. The real system is very complex, with many pipes, wires, umps and components. An objective of this exercise is for you to identify and simplify the system into your diagram.

1. Draw a diagram of the overall engine room arrangement- Include the gensets, fuel systems, cooling etc. You **do not need** to include all pumps etc but you need to be able to draw a diagram at a level of detail that it describes the entire system. The system is obviously very complex and includes many components and subsystems- so you need to make sensible decision about what to include and what to leave out.
   Include a description of the main components and layout used onboard and make sure your diagram is correctly labelled.
2. Draw simplified schematic diagrams of the
   I. Fuel Oil System for Diesel Generator
   II. Diesel Generator Cooling Water System
   III. Lubricating Oil System for Diesel Generator

Include pumps, filters, heat exchanger, coolers, sea chests etc. Use your time on board in the machinery room and the drawings made available to you to help with this. These first two tasks mean you should now have identified the arrangement and most of the machinery components.

Task 02

The first part (Q1) will be mainly based on calculations, while the second part (Q2) will be rather based on the vessel measurement data, and the third part (Q3) is designed to compare these two (calculations vs measurements).

For the calculations, use the definitions of efficiency as given in the lecture notes (e.g., technical efficiency). Use the efficiency curves and numbers given in the lecture notes for each component (genset, switchboard, …). Refer to the lecture for Hybrid power systems. Note: for this specific case, assume the load power is measured at the input of the electric motor. So, no need to consider the efficiency of the "motor" and "propeller", but just the rest of the powertrain. For the load power (Q1.ii), use the load power of the vessel, to make sure to have a fair comparison between Q1 and Q2.

1. Make the following drawings, figures and calculations.
   i. Draw a single line diagram (SLD) of the complete power system, indicating the generator sets, switchboards, and propulsion units. Mention also voltage levels on the switchboards.
   ii. Plot vessel's propulsion power for each propulsion motor (Port and Starboard) and the total propulsion power (show them in one figure). Repeat it for route 1 and route 2 (2 figures).
      a. $P_{M,i}[\mathrm{kW}]$ vs. time.
      b. $P_{Prop}[\mathrm{kW}]$ vs. time.
   iii. Calculate the power efficiency, from genset up to the propulsion motors as a function of time: plot $\eta_p[\%]$ vs time.
   iv. Calculate fuel consumption as a function of time: plot $M_f[\mathrm{Kg}]$ vs. time.
   v. Calculate total energy efficiency for the given load profile (from fuel to propulsion motors): $\eta_E[\%]$.
2. Make the following figures based on vessel's data
   i. Generated power by each DG and total supply power (all in one figure) and for route 1 and route 2 (2 figures).
      a. $P_{DG,i}[\mathrm{kW}]$ vs. time
      b. $P_{total}[\mathrm{kW}]$ vs. time
   ii. Fuel flow rate as a function of time for route 1 and route 2 (2 figures): $Q_f[\mathrm{Kg/h}]$, vs. time.
   iii. Total fuel consumption as a function of time for route 1 and route 2 (2 figures): $M_f[\mathrm{Kg}]$, vs. time.
   iv. Total power efficiency, from genset up to the propulsion motors as a function of time. Repeat for route 1 and route 2 (2 figures).
      a. $\eta_p[\%]$ vs. time.
   v. Calculate total energy efficiency, from fuel up to the propulsion motors (only based on data). Repeat for route 1 and route 2 (2 values): $\eta_E[\%]$.
3. Comparison
   i. Compare the calculated power efficiency $[\%]$ (in Q1) with the experimented power efficiency (in Q2).
   ii. Compare the calculated total fuel consumption $[\mathrm{kg}]$ (in Q1) with the experimented fuel consumption (in Q2).

Task 03

Objective of this task is to use some of the data collected on board to examine the operation of the engines only, rather than the entire energy system onboard.

1. Determine the thermal efficiency of each engine separately (DG1 and DG2) as a function of time (for the entire voyage). Use the power generated by each gen-set as the engine power- this can be done as the generator will be over 95% efficient and we often use the generator power output as the power that the engine is producing. Identify the minimum and maximum efficiency of DG1- at those two points, determine the engine torque and the BMEP. Explain the relationship you observe between the thermal efficiency, the torque and BMEP.

2. You have determined the total mass of fuel used for the entire voyage- - determine the total amount of carbon dioxide emitted for the voyage, explaining which assumptions you have made.
3. While on board- ask the engineer about the fuel tanks and system- how much fuel can the vessel carry? What is the estimated total range on a full tank? There is a plan to refit the ship to run on a zero carbon fuel- methanol (net zero). Using the current tank size- the fuel consumption and the maximum power required for the voyage and stating all assumptions- determine the tank size required, the max flow rate of fuel to the engine, would the engines need any other modifications. Limit this answer to one page please- only a basic design stage.

Task 04

It is expected that the necessary information will be obtained during the visit to R/V Gunnerus.
The groups can find some relevant documentation on Blackboard:
PI&Ds for parts of the machinery system on R/V Gunnerus, including drawing of engine rooms.
Operation manual,
There is also some data and information in the task description below.

Any further information can be found on the internet.

1. Draw a reliability block diagram for the main machinery on board the Gunnerus in normal operation (transit), i.e. when diesel generators and electric motors are in normal operation to distribute the load and optimize fuel consumption. Include diesel generators, electric motors, as well as the following auxiliary systems:
    i. Fuel Oil System for Diesel Generator
    ii. Diesel Generator Cooling Water System
    iii. Lubricating Oil System for Diesel Generator

Only major components such as pumps, filters, heat exchangers, etc. are included in this context. Pipes and cables are not included. (Here you should set up a reliability diagram for each subsystem, and then put everything together into one diagram for the entire main machinery).
Table 1 provides some relevant data for the components/subsystems. In the project, these can be considered "generic", i.e. a "pump", for example, can apply to all types of pumps.
Note that if data is missing, you must use other documentation, expert assessments and assumptions. There may also be data in the table that is not relevant to use in the project.

2. Calculate the probability of failure of the machinery system from the reliability block diagram in 1.) over a period of 3 years. Assume random failure. Also assume that any parallel systems have active redundancy.
3. Do an FMECA of the system. Include at least 5 different components and 10 failure modes (maximum 15 to limit the scope). Use the form to document the analysis (which you set up yourself) and define categories for risk (criticality). Remember to include the categories for frequencies and consequences in the report itself (as well as the form).
4. Suggest relevant maintenance tasks based on the results in 1)-4), including intervals, for the various failure modes that you found in FMECA. Discuss the results and present the recommendations.

Table 1. Failure data for some components/subsystems and some types of failure modes. The components can be considered to be "generic" for a ship.

Components	MTBF (hours or years)	MDT (timer)
Pump		
Leakage	30 000	8
Worn-out impeller	16 000	2
Won't start	24 000	8
Fracture in axle	100 000	12
Air cooler		
All fault modes	8 years	8
Heat exchanger		
Reduced/no throughput	4 years	8
Leakage	5 years	15
Filter		
Reduced/no throughput	1 year	3
Sea chest		
Leakage	10 years	10
Clogged – no flow	5 years	5
Switchboard		
Failure	50 000	10
Switch/Relay		
Failure	10 years	2
Converter		
Failure	60 000	10
Diesel generator		
Failure	15 000	20
Electric motor		
Failure	60 000	8
Won't start	100 000	15
Starter battery		
Failure (too low voltage)	30 000	10
Compressor		
Leakage	10 000	10
Failure in stock	20 000	10
Separator		
Leakage	10 000	4
Reduced quality	5 000	4
Tank		
Leakage	30 years	30
Instrument file	5 years	10
Valve		
Leakage	7 years	8
Won't open/close	10 years	8
Thruster		
Failure	10 000	120

Appendix: List of English-Norwegian terms

English	Norsk
Diesel Generator Cooling Water System	Dieselgenerator-kjølevannssystem
Expert assessment/judgment	Ekspertvurdering
Efficiency	Effektivitet/virkningsgrad
Failure	Svikt
Failure mode	Feilmode
Fuel Oil System	Brennolje-/drivstoffsystem
Failure rate	Sviktrate
Heat exchanger	Varmeveksler
Maintenance	Vedlikehold
Maintenance intervals	Vedlikeholdsintervaller
Mean down time	Forventet/gjennomsnittlig nedetid
Mean time between failure	Middeltid/forventet/gjennomsnittlig tid mellom svikt
Lubrication oil system	Smøreoljesystem
Probability	Sannsynlighet
Propulsion	Propulsjon/Fremdrift
Redundancy	Redundans
Reliability	Pålitelighet
Reliability block diagrams	Pålitelighetsblokkdiagram
Risk	Risiko
Sea chest	Sjøkiste
Switchboard	Brytertavle/bryterpanel