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RESEARCH ARTICLE

DEVELOPING THE REFERENCE ENERGY SYSTEM OF A GENERIC FRIGATE

İbrahim Türksev BENLİ[1]
Egemen SULUKAN[2]
Ahmet Dursun ALKAN[3]

[1] *Yıldız Technical University, Naval Architecture and Marine Engineering, Istanbul, Turkey*
turksevbenli@gmail.com; ORCID: 0000-0001-6531-3209
[2] *National Defense University, Turkish Naval Academy, Istanbul, Turkey*
esulukan@dho.edu.tr ; ORCID: 0000-0003-1138-2465
[3] *National Defense University, Turkish Naval Academy, Istanbul, Turkey*
adalkan@dho.edu.tr; ORCID: 0000-0002-7345-3209

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ABSTRACT

Referring 3rd IMO GHG study maritime transport is responsible for about 2.5% of global greenhouse gas (GHG) emissions emitting around 940 million tons of CO2 annually. This emission figure is projected to increase significantly if serious mitigation measures are not put in place. Thanks to the studies conducted by IMO GHG emissions from international shipping to be reduced, actually the projection of the reduction amount is 50% achieved by 2050 compared to 2008. Today, navy vessels are not responsible for the IMO emission regulations as commercial vessels, but special regulations may appear in the future. Therefore energy analysis can be needed also for the naval vessels in the future. In this paper, the initial step for performing a ship energy system analysis, which is called "Reference Energy System", has been developed for a generic frigate. The aim of this work is to provide to open a window for energy analysis of naval platforms.

Keywords: *Ship Energy System Analysis, Reference Energy System, Frigate, Emission Control Areas, Greenhouse Gases.*

GENEL BİR FIRKATEYNİN REFERANS ENERJİ SİSTEMİNİN GELİŞTİRİLMESİ

ÖZ

IMO'nun 3. sera gazı emisyonu çalışmasına göre deniz taşımacılığı yılda yaklaşık 940 milyon ton CO2 gazı salmakta ve bu da küresel sera gazı salımının (emisyon) yaklaşık %2.5'u kadardır. Ciddi önemler alınmadığı takdirde bu rakamların önemli ölçüde artacağı tahmin edilmektedir. IMO'nun yaptığı çalışmalarda, 2008 yılına kıyasla 2050 yılında deniz taşımacılığı kaynaklı sera gazı salımlarının %50 azalması hedeflenmektedir. Günümüzde donanma gemileri ticari gemiler gibi IMO'nun kısıtlamalarından sorumlu tutulmasa da gelecekte bu gemilere özel kısıtlamalar getirilebileceği değerlendirilebilir. Bu çerçevede donanma gemilerine yönelik enerji analizinin yapılması faydalı olacaktır. Bu çalışmada genel bir fırkateyn için gemi enerji analizinin gerçekleştirilmesinde ilk basamak olan Referans Enerji Sistemi çalışması yapılmıştır. Çalışmanın amacı askeri deniz platformlarının enerji analizi için bir pencere açılmasını sağlamaktır.

Anahtar Kelimeler: *Gemi Enerji Sistemi Analizi, Referans Enerji Sistemi, Fırkateyn, Emisyon Kontrol Alanları, Sera Gazları.*

1. INTRODUCTION

Population rise and technological advances have increased the energy demand enormously following the industrial revolution. Energy consumption per capita is a significant indicator in terms of the country's development level.

Fossil fuels are the primary source for the world's energy demand and used to power many vehicles including the naval vessels. However, fossil fuels are limited in nature, and diminishing day by day, while they cause harmful emissions during combustion processes, bringing the greenhouse emissions (GHG) associated with huge disadvantages.

Energy system analysis approach basically starts with providing a balance between energy leaving and entering the system with all the interactions of energy carriers including respective technologies; mainly aiming to detect and minimize the inefficiencies in a complex and detailed structure. In this way, analyzing the energy system of a ship may address the determination of more efficient technologies, or fostering new and clean fuel options, as the International Maritime Organization (IMO) commences to present and penetrate efficient technology and fuel standards in the maritime sector in the last decades.

In order to perform energy system analysis properly; a Reference Energy System (RES) should be developed. The first step of creating the RES is to define the energy sources and respective demands in the analyzed energy system. Then, these sources are classified according to their interaction within the system (i.e. whether they are entering or exiting the system), while demand technologies are grouped with respect to their utilization areas. Consequently, as the final step of RES creation, source and demand items are matched with the help of energy carriers, as well as conversion and process technologies.

Since they operate far from the mainland, ships are required to meet their own energy demands. Furthermore; ships have various systems, requiring a vast amount of energy. Therefore ships may have highly complex energy systems. The naval vessels have been ranked in the second place in terms of energy consumption within all ship classifications (surpassed only by the cruise ships), and managing these complex systems efficiently gets harder day by day.

The major energy demand items of a naval vessel are main propulsion, navigation, operation, lighting, communication, air conditioning, security, services, combat, environmental protection, health and maintenance systems.

In order to protect national benefits and interests over the world seas, states hold and develop navy fleets. In this manner, the existence of navies is also a contributor to global greenhouse gas emissions. IMO regulates greenhouse emissions by setting standards that should be met by maritime vessels. Although these limitations are not for military vessels today, this situation may not be permanent.

Naval ships are classified into many different categories according to their objective functions and operational characteristics. In this paper, the RES model is created for a generic frigate. Frigates are the high-speed military vessels with lengths from 80 to 150 meters and within all types of warships; they have the widest mission range varying from anti-air missile to submarine defense. Since frigates perform a wide range of tasks, they have many different systems with high energy demand. Furthermore, high-speed requirements necessitate the use of high energy consuming propulsion systems. Moreover, large crew size is another contributor to the required amount of energy.

1.1. Related Literature

Baldi had performed energy analysis for two commercial vessels. He reported that the maritime industry activities have increased, fuel prices have soared, and more stringent environmental regulations have been developed. Moreover; he discussed that although its contribution to global warming is relatively low today, maritime transport should be examined in order to decrease related greenhouse gas emissions, and highlighted that there is room for improving the energy efficiency of vessels and that maritime industry can be a part of a sustainable economy [1].

In another related analysis; Sarı *et al*. claimed that the ever-increasing population and rapid technological developments led to an increase in energy consumption and a corresponding increase in demand while decreasing the availability of global resources. They affirmed that energy system analysis has been a hot topic and evaluated the energy consumption and respective demand by developing a reference energy system (RES) model of a generic ship [2].

With IMO's current regulation, on-force by January 1st of 2020, the amount of sulfur in marine fuels will be limited to 0.5% of total fuel mass. Moreover, IMO's limit for the share of sulfur in fuel has already been 0.1% for Emission Control Areas (ECAs) since 2015 [3].

Figure 1. Current and future Emission Control Areas [4].

Trivyza *et al.* set up a simulation model to predict the energy systems' performance during the ship lifetime. This study introduces an innovative method that integrates the economic and environmental aspects of sustainability [5].

In this perspective, Evrin *et al.* have developed an integrated energy system based on hydrogen fuel. In order to supply the ship's electric and fresh water needs, where liquefied hydrogen fuel is used in the steam production cycle. Moreover the hydrogen fueled engine's effectiveness at decreasing greenhouse gas emissions is assessed in this study [6].

Yuan *et al.* assert that shipping contributes heavily to global CO_2 emissions and improving the ship's energy efficiency is an important area of interest. Authors denote that, ship's fuel consumption should be decreased to decrease the ship emissions. However, evaluating ship's fuel consumption with the physical system and simulation models is hard due to factors; such as complexity of the ship energy system, complexity of real-life operational conditions, and variations in real-life weather conditions. In this study, a Gauss process metamodel was developed to estimate ship fuel consumption for different scenarios. This model takes into account the effects of not only operational conditions such as speed and trim, but also weather conditions such as wind and wave [7].

In their study, Baldi *et al.* assert that better utilization of the ship's energy improves a ship's energy efficiency significantly. In order to demonstrate this method's benefits, the authors highlight the importance of applying ship energy system analysis. Data collected from the case study ship's operations are used in conjunction with ship systems' mechanic information to evaluate different energy flows [8].

Gutiérrezet *et al.* declare that several different methods were suggested to measure the ship's fuel consumption and emissions more reliably and that whichever of these methods is the best is still undecided. In this study, four common methods for calculating energy consumption and emissions are compared via a case study. The goals of this comparison are to obtain data needed for better energy management and to determine the best method for applying to any ship [9].

Grados *et al.* discuss the energy and emission calculations problems of ships; however they conclude that energy consumption and emissions should be taken as the key factors when calculating the real power generated by the ship's main machines. In order to evaluate the propulsion system's effect on calculated energy consumption and emissions, data gathered from eight ferries operating at the strait of Gibraltar. For this calculation, after comparing four methods, the authors suggest a different method for these eight cases [10].

1.2. The Significance of Ship Energy System Analysis

Relevant researches show that shipping-related greenhouse gas emissions will increase by 150% to 250% by 2050 when compared to 2008 levels [11]. As a result, maritime transport caused CO2 emissions will constitute 17% of the global total by 2050 [12]. Energy system analysis, by increasing the energy efficiency of a vessel, allows lower fuel consumption and emissions. The vitality of such an analysis becomes more evident when factors such as IMO's more aggressive greenhouse gas emission targets and rapid depletion of fossil fuel sources are considered. Furthermore, for naval vessels, efficient energy management contributes to survivability, thus making this paper even more significant.

2. METHODOLOGY

2.1. Energy Activity Calculation

A number of variables, which affects the result, are used for energy systems calculations. These variables are final energy demand and useful energy demand.

2.1.1. Final Energy Demand

Activity levels are multiplied by both energy demands and energy densities to determine the average energy consumption of each device or system and the energy consumption is calculated annually.

$$D_{b,s,t} = TA_{b,s,t} \times EI_{b,s,t} \tag{1}$$

In Equation (1), D refers to the energy demand, TA is the total activity. EI is energy intensity. b is the energy demand system or devices, s is the scenario and t is the time and is taken as a year. Activity level is defined as the amount of time that and the amount of load at which the device is used, in a period of time.

2.1.2. Useful Energy Demand Analysis

In useful energy analysis, total energy consumption is affected by the fuel type, energy efficiency and available energy density.

For each technology branch:

$$UE_{b,\,0} = EI_{AG,\,0} \times FS_{b,\,0} \times EFF_{b,\,0} \tag{2}$$

b index stands for the user-defined demand technology; while *UE*, *EI*, *FS*, and *EFF* refer to useful energy, energy intensity, fuel share, and the efficiency of technology, respectively.

The following example illustrates the final and useful energy demand calculation. Consider an aggregate energy branch with a final intensity of 100 GJ per activity, the electricity technology has 20% and diesel technology has % 80 fuel shares. Electricity technology has an efficiency of 100% and diesel engine technology has an efficiency of 45%. Therefore, the useful energy intensities of the relevant technologies are 100×20%×100% = 20 GJ/activity and 100×80%×45% = 36 GJ/activity respectively, and the activity shares are 20/56×100% = 35.7% and 36/56 = 64.3%, respectively.

Table1. Example of useful energy and activity share calculation

	Final Intensity		Useful Intensity	
Heat	100		56 GJ	
	Fuel Share	Efficiency	Useful Energy	Activity Share
Electricity	20	100%	20 GJ	35,7%
F-76 (Diesel)	80	45%	36 GJ	64,3%

2.2. Transport Analysis Calculation

$$Stock_{t,\,y,\,v} = Sales_{t,\,v} \times Survival_{t,\,y-v} \quad (3)$$

$$Stock_{t,\,y} = \sum_{0}^{v} Stock_{y,v,z} \quad (4)$$

Where t is technology branch, v is the model year, y is the calendar year, t is the number of types of vehicles. Sales are the number of vehicles added in a particular year: entered as an expression. The *stock* is the number of vehicles existing in a particular year, and v is the maximum number of vintage years.

$$FuelEconomy_{t,\,y,\,v} = FuelEconomy_{t,y} \times FeDegradation_{t,\,y-x} \quad (5)$$

FuelEconomy is fuel use per unit of vehicle distance traveled. FeDegradation is a factor that equals 1 when y=v and representing the decrease in fuel economy depending on vehicle age.

$$Mileage_{t,\,y,\,v} = Mileage_{t,\,y} \times MlDegradation_{t,\,y-x} \quad (6)$$

Mileage is the annual distance traveled per vehicle and entered as an expression, defining the historical values and how that variable changes over time from the first scenario year to the end year of the study period. *MlDegradation* is a factor representing the change in mileage as a vehicle gets obsolete; it equals 1 when y=v [13].

$$EnergyConsumption_{t,y,v}=Stock_{t,y,v} \times Mileage_{t\,y,v} \times FuelEconomy_{t\,y\,v} \quad (7)$$

2.2. The Reference Energy System Concept

A simple definition of RES is the flow of energy from primary sources through conversion and process technologies to demand items, as illustrated in Figure 2 [14].

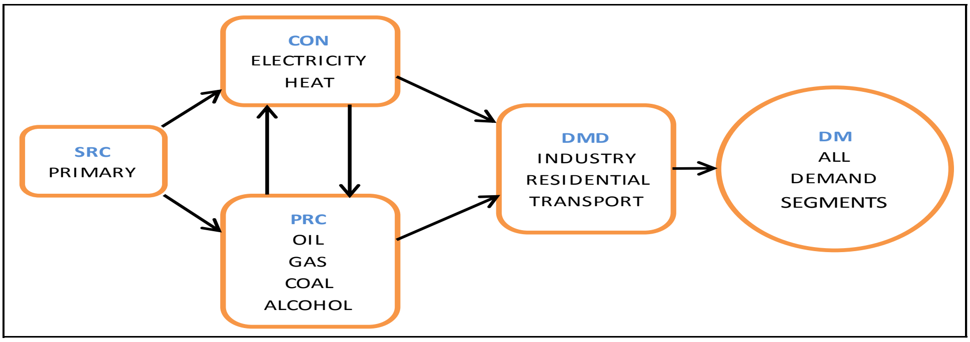

Figure 2. A generalized RES

As a generic frigate has been the subject to this paper's analysis, the RES scheme has been created based on specified demands of a frigate and the energy sources needed to meet these demands. Then, the demand technologies of the frigate have been determined.

2.2.1. Demand Technologies

There are various demand items in a frigate and each demand item exists in the vessel for a specific purpose. For instance, different types of energy technologies are getting used for lighting e.g. lamps, luminaires and projectors. Subsequently, the specific operation voltage and frequency values for each demand item were determined accordingly.

2.2.2. Demands

After determining the demand items, these items were grouped into categories according to their functions. Diesel generators and bow thruster are both responsible for the propulsion of the vessel; therefore they are listed under the "Main Propulsion System" group. Similarly; GPS and gyro compass are the parts of the "Navigation" group. This kind of classification allows a better overall understanding of the energy requirements and flow of energy in a frigate. Moreover, calculating these demands in each category and respective energy requirements will provide a base and guidance for further studies and ship design activities. The frigate's demand technologies and their corresponding groups are listed in Table 2, 3 and 4.

Table 2. Demand technologies and respective demands (1)

MAIN PROPULSION SYSTEM	NAVIGATION
BOW THRUSTER	GYRO COMPASS
LUBRICATION OIL AND TRANSFER PUMP	WINDLASS MANEUVER
FUEL FILLING AND TRANSFER PUMP	ANCHOR WINDLASS
MONITORING AND CONTROL	NAVIGATION RADAR (LPI)
PROPULSION SHAFT AND COUPLINGS	WECDIS
REDUCTION GEAR LUB.OIL.PUMP	FIN STABILIZER SYSTEM
REDUCTION GEAR STAND BY PUMP	SHIP WHISTLE
FUEL SEPARATOR	DYNAMIC AUTOPILOT SYSTEM
OIL SEPERATOR	NAVTEX
MAIN ENGINE AIR VACUUM SYSTEM	GPS
MAIN ENGINE WASHING SYSTEM	DGPS
MAIN ENGINE STARTING SYSTEM	NAVIGATION AND SIGNALLING LIGHT
MAIN PROPULSION SYSTEM CONTROL BOARD	ECHO SOUNDER
STERN TUP SYSTEM	ANEMOMETER
COOLING WATER SYSTEM	DATA DISTRIBUTION UNIT
RUDDER ENGINE	DOPPLER LOG
GOVERNORS	WINDOW WIPER
DIESEL GENERATOR SET	METROLOGICAL MEASUREMENT SYSTEM
MAIN PROPULSION ENGINE	SIGNAL REPEATER
OPERATION	**COMMUNICATION**
SONAR	CRYPTO DEVICE
DEGAUSSING SYSTEM	WARNING SPEAKER
BOAT LAUNCHING ARRANGEMENT	ANNOUNCEMENT SYSTEM-1
VEHICLE CRANE	ANNOUNCEMENT SYSTEM-2
SEVICE CRANE	SATELLITE COMMUNICATIONS SYSTEM
TRANSFER SYSTEM	UHF RECEIVERS
UAV OPERATOR CONSOLE	MF/HF/LF RECEIVERS
USS OPERATOR CONSOLE	FIRE ALARMS
SUBMARINE DIVE LAUNCHING ARRANGEMENT	ALARM DOOR LOCK
UAV WEAPON SYSTEM	IFF
UAV FUEL TRANSFER SYSTEM	GMDSS
ANTISUBMARINE WEAPON TRANSFER SYSTEM	OTHER ALARM SYSTEM
SUBMARINE CHARGE UNIT	MESSAGE COMMUNICATION SYSTEM
AIR COMPRESSOR	X-BAND ANTENNAS
PRESSURE ROOM COMPRESSOR	HF TRANSCEIVERS
HELICOPTER HANGAR COVER MOTOR	VHF LOW BAND TRANSCEIVERS
HELICOPTER TRANSFER SYSTEM	VHF/UHF TRANSCEIVERS
JP-5 FUEL TRANSFER SYSTEM	UNDERWATER TELEPHONE
DIVE COMPUTER	S/P TELEPHONE
PRESSURE ROOM MONITORING SYSTEM	HAND RADIOS
VIDEO MONITORING UNIT	SHIP INTERCOM SYSTEM

Table 3. Demand technologies and respective demands (2)

SERVICE	MILITARY SYSTEM / SECURITY /
COLD ROOMS	TEST PANEL ELECTRONIC WORKSHOP
REVERSE OSMOSIS DEVICE	ANTENNA CONTROL AND COOLING DEVICE
MACHINE WORKSHOP	ED TRANSFORMER
SOLID WASTE DEVICE	GUN POWER AND ESCALATOR CABINET
WASHING MACHINE	GUN LIQUID COOLING CABINET
IRONING MACHINE	MACHINE GUN
CYLINDRICAL IRONING MACHINE	FREQUENCY DISRUPTORS
BOILING POT	TORPEDO BARREL COVER
RANGE	WEAPON CRANE
GRILL	AMMO TRANSFER ELEVATOR
OVEN	BRIDGE DISPLAY AND CONTROL UNIT
WASHING MACHINE	BRIDGE LANCER REMOTE CONTROL UNIT
MIXER MACHINE	CONTROL RADAR
FRYER	LIGHTING RADAR
FRYING PAN SYSTEM	FIBER OPTICAL DIRECTOR
FERMENTATION CABINET	AIR DEFENSE MISSILE IGNITION SYSTEM
GARBAGE GRINDER	VERTICAL LAUNCHER SYSTEM
BOOSTER SYSTEM	3D SEARCH RADAR
MEAT MACHINE	12.7 MM HEAVY MACHINE GUN
LAUNDRY DRYER	CIWS
POTATOES PARING MACHINE	GUN CONTROL SYSTEM
ELECTRIC STOVE	TORPEDO
MICROWAVE OVEN	AIR TARGETS CHEATING SYSTEM
TEA MACHINE	UNDERWATER DECEPTION SYSTEM
HOT SERVICE UNIT	ELECTRONIC WARFARE SYSTEMS
FRIDGE	USER CONTROL INTERFACES
WATER TREATMENT EQUIPMENT	HEADQUARTERS COMPUTER SYSTEM
WATER HEATER	COMMAND CONTROL DEVICES
UV FILTER	BRIDGE CONTROL UNIT
CHLORINE DOSING UNIT	DIVER PUMP
PAPER CROP MACHINE	PORTABLE FIRE HAMPER
CALL DEVICES	MAIN FIRE AND AUXILIARY SEA WATER PUMP
FREEZING	MAIN FIRE PUMP
BREAD CUTTING MACHINE	MAN OVERBOARD ALARM
TOASTER	DAMAGE CONTROL PANEL
BLENDER	NBC SYSTEM
COFFEE MACHINE	CAMERA SYSTEM
TOASTER MACHINE	FIRE ALARM SYSTEM
MEAT GRINDER	FOAM FIRE EXTINGUISHING SYSTEM
PRINTER	FIRE FIGHTING SYSTEM WITH GAS
TELEVISION	GAS DETECTOR
SOUND SYSTEM	CARD READERS
RADIO	FIRE DETECTOR
DVD PLAYER	DENTAL SEAT SYSTEMS
SATELLITE RECEIVER	X-RAY MACHINE
SEWING MACHINE	STERILIZED DEVICE
BARBER EQUIPMENT	SHOCK DEVICE

Table 4. Demand technologies and respective demands (3)

LIGHTING / AIR CONDITIONING	ENVIRONMENTAL PROTECTION / MAINTENANCE
OUTDOOR DECK LIGHTING SYSTEM	DIRTY WATER PUMP
EMERGENCY LIGHTING	BILGE DISCHARGE PUMP
HAND LIGHTING	BILGE SEPARATORS
LUMINAIRES AND PROJECTORS	MUD PUMP
INDOOR LIGHTING	OIL SEPARATOR FILTER
CEREMONY LIGHTS	MUD TANK DISCHARGE PUMP
ENTRANCE LAMPS	WASTEWATER VACUUM PANEL
DOOR LIGHTING	SLUDGE TRANSFER PUMP
CHILLER WATER PUMP	ANTI-FOULING SYSTEM
BOILER SYSTEM	ACTIVE CATHODIC PROTECTION SYSTEM
HEATER	SHARPENING ENGINE
HUMIDITY REGULATOR	DRILLING
AXIAL FAN	WELDING EQUIPMENT
RADIAL FAN	RIVET GUN
HOT WATER CYCLE PUMP	AIR HAMMER
COOLING WATER CYCLE PUMP	PAINT SPRAYING MACHINE
	PORTABLE AIR DRYING DEVICE

2.2.3. Resource Technologies

Resource technologies are the energy sources that are used in the system. Following the determination of the demand technologies, resource technologies are specified depending on the energy carrier types and associated fuels. These sources can be classified into two groups: primary and secondary energy sources.

Primary energy sources; such as crude oil, wood, coal, and geothermal energy, are available in nature. On the other hand, secondary energy sources, such as gasoline, diesel, and electricity-are not available in nature. However, they can be derived from primary energy sources.

In the RES scheme for the frigate, used energy sources are F-76 diesel fuel, lubrication oil, sea water, electricity, and gasoline. F-76 is the common NATO standard fuel used by naval ships. Lubricating oil is required for the friction reduction, wear protection, and cooling of the moving parts of the main engines. In addition, some of the lubricating oil is consumed due to thermal evaporation during the operation in the diesel engines. Seawater is an unlimited source, which is used for cooling purposes. Electricity is required for the operation of various systems in the vessel. Gasoline is used to power rescue boats and rigid inflatable boats.

Although all of the energy sources mentioned above enter the system (input sources), a certain amount of them leaves the system. For instance, the excess amount of F-76 fuel can be transferred to another vessel, lubricating oil can be consumed during the diesel engines operation, and after being used for cooling purposes, heated sea water can be discharged.

2.2.4. Conversion and Process Technologies

The conversion and process technologies that can be found in a frigate are the main propulsion engine, diesel generator set, auxiliary propulsion engines, fuel separators, oil separators, main switchboards, transformers, converters, inverters, and batteries. These systems form a bridge between source and demand technologies. For instance; F-76, as an energy carrier, enters the diesel generator set, where it is converted to heat mechanical and electrical energy, respectively. Then the electrical energy produced by the generator is transmitted to the main switchboard, which distributes the energy to the various demand technologies.

Figure 3. The simplified representation of energy flow.

2.2.5. Primary and Final Energy Carriers

Primary energy carriers, such as pumps and compressors, transport the source energy to conversion and process technologies. Each system in the vessel has a different energy demand. Some of them need electrical energy, while others require heat energy. Furthermore, voltage and frequency requirements can vary among the demand technologies in need of electrical energy. Final energy carriers are these different forms of electrical energy, as well as heat energy, directly consumed in the end-use technologies.

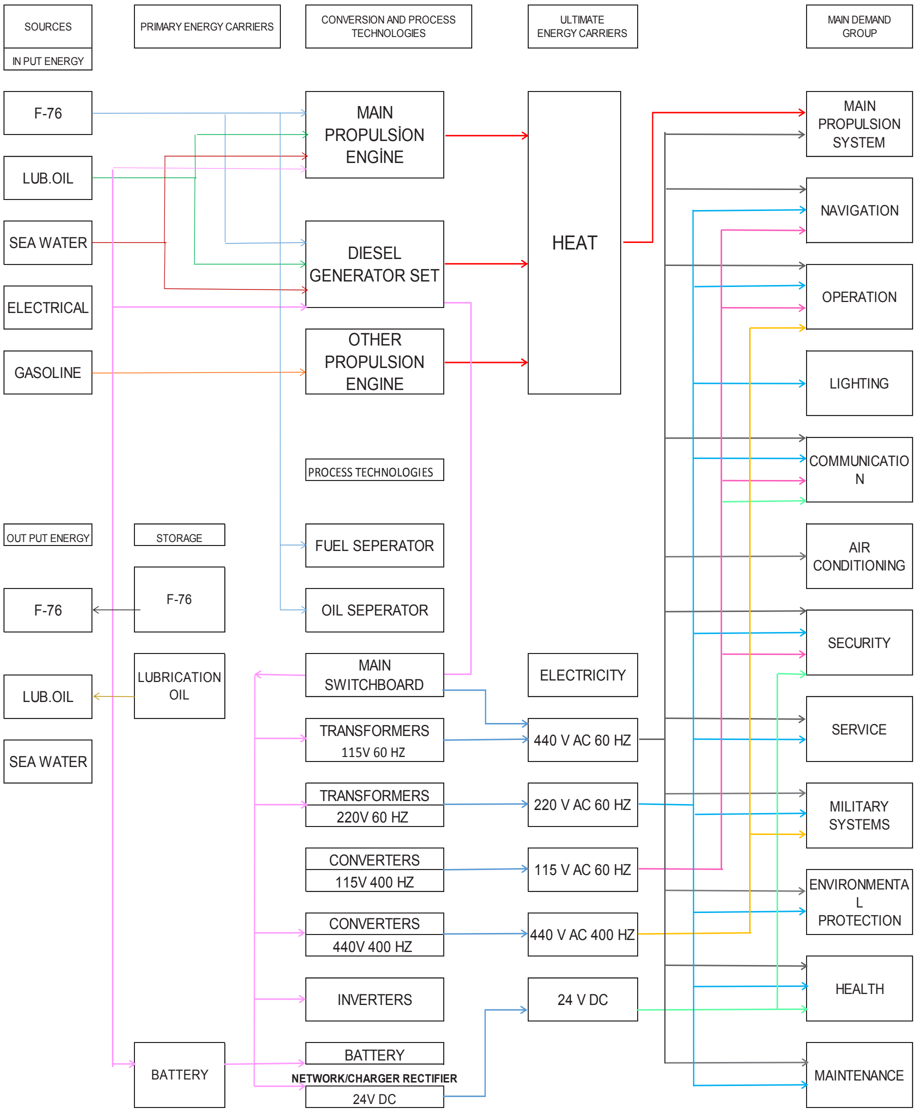

Figure 4. Reference energy system for a generic frigate

5. RESULTS AND CONCLUSION

Energy technologies utilized onboard in a frigate support the main objective function of the ship. The number of energy demands are determined in the contract design phase, then verified during the final sea trials. However, the decision makers may need a detailed energy profile of the ship to address decent arrangements for the possible modifications on the ship configuration, both for the technical and environmental perspectives. With this motivation, a detailed scheme named RES is developed for a generic frigate in this study. The technical parameters for a generic frigate are shown in Table 5, corresponding to each title in the main demand group as illustrated in Figure 4. The calculations are shown only for navigation and lighting demands in Table 5 for “gyro-compass” and “emergency light” under navigation and lighting groups are explained to give a better insight.

In the analyzed energy system of a frigate, two gyro-compasses are on board. Both have an operating voltage of 220V, use alternative current (AC), and have an operating frequency of 60 Hz. Two gyro-compasses use a total of 15 kW energy per hour. Gyro-compasses are used during the navigation, therefore usage percentage of gyro-compasses (%25) is taken from the ship’s annual navigation duration. From the usage percentage, the time interval of gyro-compasses usage is calculated as %25×365×24. Then, utilization factor (1 for gyro-compass) is multiplied with this annual usage duration (2190 hours) and load per hour (15 kWh), in order to find the total annual load (32850 kWh), and also shown in Gigajoule in a different column. Similarly, there are 400 emergency lights on board. However, emergency lights operate at 220V AC under normal conditions, and could be switched to 24V DC in an emergency, as they can operate both alternative (AC) and direct (DC) current.

Table 5. Technical parameters and information for energy system modelling of a generic frigate

SYSTEM	AMOUNT	VOLTAGE (V)	CURRENT TYPE	FREQUENCY (Hz)	ELECTRICITY USAGE PER HOUR (kWh)	ELECTRICITY USAGE PER YEAR (kWh)	USAGE HOUR PER YEAR	TOTAL USED QUANTITY GIGA JOULE (GJ)	UTILIZATION FACTOR	USAGE FACTOR
NAVIGATION										
GYRO COMPASS	2	220	AC	60	15	32850	2190	118,2272	1	0,25
DYNAMIC AUTOPILOT SYSTEM	1	115	AC	60	28	61320	2190	220,6907	1	0,25
ANEMOMETER	1	115	AC	60	0,7	1533	2190	5,517267	1	0,25
DGPS	1	220	AC	60	1,2	2628	2190	9,458172	1	0,25
GPS	1	220	AC	60	1,2	2628	2190	9,458172	1	0,25
NAVTEX	1	220	AC	60	2	4380	2190	15,76362	1	0,25
DATA DISTRIBUTION UNIT	4	220	AC	400	7	15330	2190	55,17267	1	0,25
DOPPLER LOG	1	115	AC	60	1	2190	2190	7,88181	1	0,25
WINDOW WIPER	12	115	AC	60	6	13140	2190	47,29086	1	0,25
ANCHOR WINDLASS	2	440	AC	60	86	6780,24	78,8	24,40208	0,9	0,009
WINDLASS MANEUVER	4	440	AC	60	85	6701,4	78,8	24,11834	0,8	0,009
WECDIS	1	220	AC	60	4	315,36	78,8	1,134981	1	0,009
NAVIGATION RADAR (LPI)	3	440	AC	60	22	48180	2190	173,3998	1	0,25
ECHO SOUNDER	2	115	AC	60	1,3	2847	2190	10,24635	1	0,25
NAVIGATION AND SIGNALLING LIGHT	84	220	AC	60	17,5	38325	2190	137,9317	1	0,25
SHIP WHISTLE	1	440	AC	60	16	35040	2190	126,109	1	0,25
FIN STABILIZER SYSTEM	2	440	AC	60	135	295650	2190	1064,044	0,8	0,25
METROLOGICAL MEASUREMENT SYSTEM	1	115	AC	60	1,4	3066	2190	11,03453	1	0,25
SIGNAL REPEATER	15	115	AC	60	4	8760	2190	31,52724	1	0,25

LIGHTING										
OUTDOOR DECK LIGHTING SYSTEM	12	220	AC	60	4	17520	4380	63,05448	1	0,5
EMERGENCY LIGHTING	400	220/ 24	AC/ DC	60/~	90,2	3950,76	43,8	14,21879	1	0,005
HAND LIGHTING	60	220	AC	60	0,6	26,28	43,8	0,094582	1	0,005
LUMINAIRES AND PROJECTORS	4	220	AC	60	6	262,8	43,8	0,945817	1	0,005
INDOOR LIGHTING	540	220	AC	60	19,44	136235,52	7008	490,3116	1	0,8
CEREMONY LIGHTS	300	220	AC	60	3	394,2	131	1,418726	1	0,015
ENTERENCE LAMPS	32	220	AC	60	0,3	1051,2	3504	3,783269	1	0,4
DOOR LIGHTING	60	220	AC	60	1	8760	8760	31,52724	1	1

In conclusion, a ship consists of a highly complex energy network with subsystems and a great number of energy devices. Therefore, estimating the energy demand of a ship may be a challenge. In order to evaluate the ship's energy system correctly; first, the amount and the type of energy required by each system should be determined. Energy is transmitted first from sources to conversion and process technologies, and then from them to demand technologies. In naval vessels, energy should be used correctly due to high demand and long-lasting operations. Hence, energy analysis is important for improving the ship's survivability. If the energy demand is known exactly, the sources can be adjusted precisely. Such energy system analyses for different types of naval vessels will support energy-decision processes in the future.

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