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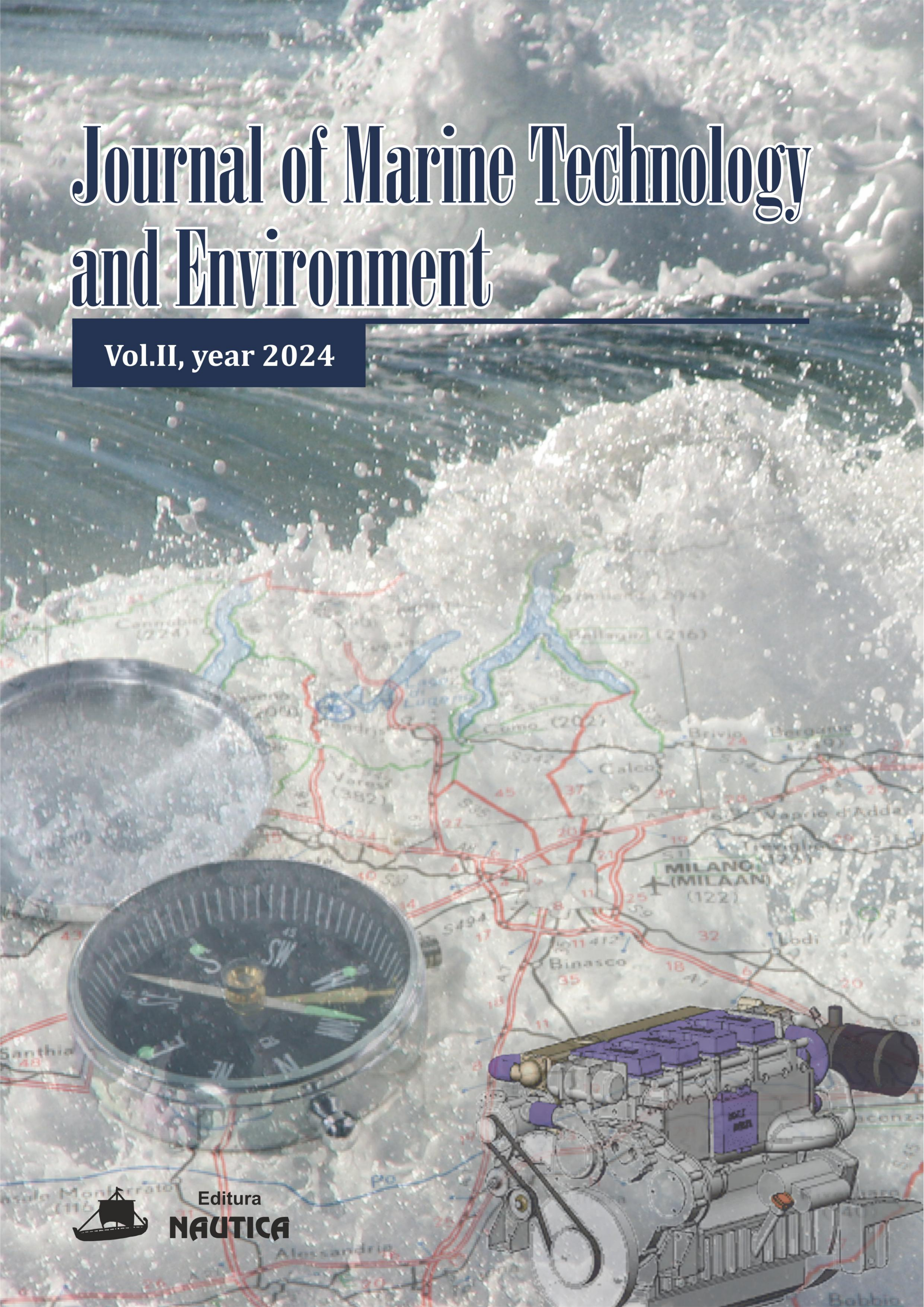

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A review of the harvesting methods for offshore renewable energy – advances and challenges

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Abstract : The present work offers general information about present-day and developments in offshore renewable energy, specially of wind, wave and the solar energy harnessing structures. In the introduction, the authors raise awareness of the despite more untapped potentials that exist in the oceans and the offshore Wind Energy Market that is experiencing a steep rise in the recent past due to technological advancement and the great policies that support this energy source. This mainly focuses on the very huge additionality of offshore wind power and the improvements in floating solar PV systems.

Section three outlines an assortment of studies that were done by different writers on the strengths and weaknesses of offshore renewable energy technologies through a meta-analysis of the literature. The method of data extraction revolved around several factors, namely technological admissibility, resource identification, location and environmental and economic factors. The sources used comprised of scholarly articles published within the peer reviewed journals in the period of 2013 to 2024, to ensure that the study offered a comprehensive analysis on the technological advancements.

The results and discussion section gives an analysis of the results achieved and demonstrates the developments in Offshore Wind Energy, Wave Energy Conversion, and Floating Solar PV Systems. Thus, offshore wind energy is described as the rapidly evolving segment and particular focus is made on the floating wind farms and their advancements in the aspects of power density and structural stability. Wave energy converters are discussed regarding their applicability to complement hybrid electricity production despite limited data on the devices' performance. Another key feature is that the FFPV systems are reported to be more efficient and cheaper than the land mounted systems.

Thus, the article emphasizes the need to produce the further literature on offshore renewable energy, political support, and cooperation between different sectors. It concludes that an offshore renewable energy has the potential for the future development due to advancement in the technology as well as due to environmental factors.

Keywords: offshore renewable energy, solar energy, wave energy, wind energy

1. INTRODUCTION

The demands of energy have augmented in the recent past which has prompted much interest on the offshore resources for wind, wave and solar energy. [1] Offshore renewable energy represents one of the most promising ranges of options in the search for the future of the planet. Moving concerned the usage of ocean power, we face quite immense and still unexplored potential in the forms of absolutely constant and seemingly inexhaustible wind, wave, and solar energies. Technological advancement has signaled this potential in recent years and notably offshore energy via vectors like wind, waves, currents, tides, etc. [2] Progress in floating solar PV technology enables us to produce electricity with astounding effectiveness while overcoming limitations like limited access to land resources; also, the system's durability is optimized. [3]

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The development of offshore energy is one of growth as well as constant change. Marine environment offers a special chance to develop the renewable energy sources like wind, which has recently undergone rapid development because of changes in policy environments and radical enhancement in technical capabilities. [2] Wave energy technologies despite being at their infancy are implemented to capture the ocean's wave energy and are part of a diverse power source which is secure and reliable. [4]

Use of non-renewable sources to generate energy is on the decline in the developed countries of the OECD membership. On the contrary, the Offshore Wind-Energy industry is growing rapidly with the current Compound Annual Growth Rate of 15. 1% in OECD countries in 2016 [5][6] and over four-fold from 1200MW in 2016. 2 GW to 18. 7 GW between 2010 and 2017 [7].

Offshore wind has become a success story of the renewable power sector supported by the advancement in technology such as floating platforms where winds are even stronger several miles off the coast. [3] Blending floating PV with wind and wave systems will transform the generation of electricity by providing zero emissions solutions and cohesiveness between the types that ultimately improves the efficiency with which electricity is produced. [3] The issues for future offshore renewable energy sources still encompass the creation of economic efficient harvesting techniques. [8]

Our study of this novel area provides understanding of the overall picture of related technologies. It seems we are witnessing the emergence of the so-called 'floating photovoltaic systems', with the observed tendencies of installation costs being lower that, combined with the effective ways of thermal control that could contribute to the increase in performance by 5-7% as compared with the systems installed on the land. [3] As we continue to see the efficiency of offshore wind farms as given by newly developed sensor technologies in the maintenance of wind farms then these energy projects promise to be economically efficient in the enhancement of system reliability. [3]

Wave energy utilization also has a great potential in the generation of offshore renewable energy resources. Hydro electric generators which convert the mechanical motion of the water waves into electrical power are reliable source of energy. From the series of advancement, wave energy technologies are still in the developmental stages, but they can support the hybrid systems more efficiently and provide power consistently with the other renewable energy systems. Floating solar system also increases the efficiency of wave energy by incorporating it with photovoltaic floating technique [3] Innovation 2023 Designing the future of wave energy.

The integration of offshore wind and wave energy systems with the integration of floating solar PV is a good strategy of production of energy in the sea. Energy storage systems proposed in [9] It is potentially a zero-emission system that can interconnect with other renewable power systems to inspire competition between energy storage systems and other renewable energy resources. Therefore, as the offshore renewable energy goes on, it is rather evident that this innovative niche expands and holds a great promise for a green and conscious world. In our modern society, research has shown a rich potential of offshore energy such as wind, wave, current and tides. [2]

Given these appraisals, most countries are working to avoid further ongoing warming by slashing carbon emissions [10] and OWE is gradually becoming a feasible strategy in this process. The development of the offshore wind-energy source is phenomenal, which reflects the growing attention and confidence in getting involved in the usage of renewable energy. Such increase in capacity of offshore wind generation can be attributed to increasing technology efficiency, better policies and regulatory environment, and inherent suitability of the offshore wind conditions at the sea. [11] As the global population attempts to decrease the amount of carbon emissions and distinguish itself in the continuous process of climate change, Offshore wind energy seems to be an ideal solution. This makes the offshore wind farms service the energy demands of coastal regions and even provide energy to the inland regions due to their scalability and efficiency. This transformation to the use of renewable energy is in conformity with the global move towards the phase out of the excessive utilization associated with the creation of energy that is both sustainable as well as with minimal carbon content. There were preceding concerns voiced in the literature by other authors, for instance, [12] or [13].

This paper uses a large body of literature and syntheses/noteworthy meta-analyses from forty-one international studies [14], which studies the spatial industry trends of offshore wind energy, which gives an understanding of how offshore wind energy is planned and developed according to best practices. [15]

These turbines are able to produce significant capacity of electricity, the place for Offshore wind farms are suitable for coastal areas and can export powers to the inland areas as well. Next, there is wave energy that we can consider as another forward area of the offshore renewable energy production. This is because just like the normal electrical devices, wave energy devices harness the mechanical wave movement and convert it into an environmental friendly electricity. [16] Similarly, [17] reportedly that wave energy has the potential to transform the world and boost its economy.

Collectively, these documents identify abundant opportunities in the development of offshore renewable energy and stressed the need for continued research and implementation of policy for offshore renewable energy for the greater good for the future. [18]

2. MATERIALS AND METHODS

The following part of this paper describes the systematic approach applied for the evaluation of the existing and potential potential of offshore REFs with

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the emphasis on the wind, wave, and solar power conversion equipment. This study adopted a review research methodology whereby the previous studies on this subject were considered with the following techniques; literature review, meta-analysis, and an assessment of cases to determine the recent developments and innovation in this field.

2.1. Literature Search and Selection Criteria

Thereby, the systematic literature review was carried out after searching the electronic databases such as Clarivate Analytics, Elsevier in addition to other scholarly repositories such as Web of Science, Scopus, Google Scholar. In our research, key terms such as “offshore renewable energy”, “offshore wind power,” “wave energy conversion”, “offshore solar energy” and similar specifications tightly connected with the mentioned field were employed during the search process. The criteria for inclusion of articles included the articles that were published in refereed scholarly journal articles between 2013 and 2024 with emphasis on the articles that have made considerable inputs to advancement of technology and research in sustainable energy. [15]

In this research article, we applied a wide cross-section of peer-reviewed research studies to build a composite knowledge of technological practicability, advantages, and complications connected with hybrid offshore energy systems that involved wind, wave, hydro, and solar energy. [19][20] Thus, the data extraction and analysis for offshore wind energy were techno- logical and showed that a floating wind farm could establish power densities of up to 57. 5 MW/km^2, which is much higher than individual SCs with steadier power co-efficients. [3]

Moreover, in the case of wave energy we established the use of hybrid systems of offshore wind and WECs stressing the possible advantage of such an approach in terms of overall efficiency and system availability. But, there is limited research on technical guidance to limit the insertion of such practices. [12] Based on solar energy, trends suggested an increase in implementing floating photovoltaic systems because of the operational efficiency and lower costs compared to fixed-on-land systems. [3] Last, environmental reviews revealed impacts of renewable technologies on the environment with a focus to the benefits of FSOPs on water quality [3] all the PDF sources provided significant insights that helped in developing the comparative analysis of the state of the art in offshore renewable energy harvesting.

2.2. Data Extraction and Analysis

What we did is to grab data from the chosen publications as comprehensively as possible so that all the characteristics relating to deployment and performance of offshore renewable energy technologies are covered. We had several parameters on board through which a lot of scattered knowledge from different papers was aggregated and synthesized for us to get a complete picture of the technology landscape.

The extraction prioritized both qualitative and quantitative data points, including types of technology (which were fixed-bottom, floating wind turbines, wave energy converters, solar panels), operational principles (aerodynamic, hydrodynamic, photovoltaic efficiencies), installed capacity (megawatts installed and potential megawatt capacity), efficiency (energy conversion rates), locations of deployment (geo-spatial distribution of technology installations), environmental impacts and economic aspects (cost and benefit analyses, potential environmental mitigation strategies).

The data that was collected underwent an extensive approach:

Technological Feasibility and Infrastructure: To evaluate infrastructure progression over time, it took into account the maximum viable water depth for fixed-bottom and floating foundations. [15] These parameters are used in selecting sites for wind energy installations because they determine whether these technologies can be located and deployed or not. [21]

- **Resource Assessment:**

This component encompassed wind resource evaluation involving model-based estimates, satellite observations to map and predict power densities, as well as practical assessments of wind farm capacities. It ranged from local to global scales taking into account operational costs related with resource assessment. [15]

- **Site Selection Analysis:**

Site selection studies were considered when selecting ideal locations for OWE developments. The number of GIS parameters used, maximum water depth restrictions applied for both fixed-bottom and floating foundations and resolution of wind and bathymetric data were some site selection parameters. [15]

- **Planning Assistance for OWDE**:

Studies that fell under planning assistance were reviewed in terms of the approaches they used, which included economic and parameter weighting analytical techniques. [22] These had different analysis approaches starting from cluster analysis to Bayesian belief networks such as evaluating spatial industry trends and involving expert opinions. [15]

- **Economic plus Environmental factors**:

These comprise studies that gave insights into the economic efficiency of various offshore renewable technologies and their environmental impacts. This covered technology life-cycle considerations, energy cost-effectiveness. [23]

2.3. Meta-Analysis

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A meta-analysis was carried out to understand emerging trends of the subject region's practices. We evaluated statistical data from literature sources on offshore wind energy, focusing on aspects such as GIS studies' resolutions about offshore wind energy installations site selection and viability of floating technologies. [15]

2.4. Case Study Evaluation

Case studies were meticulously chosen to provide practical applications and real-world examples of offshore wind, wave, and solar energy systems. The criteria for selection included the representation of each technology's potentiality and its challenges. Examples gave out crucial information concerning how each type of energy harvesting system was designed, operated with efficiency, produced power and required maintenance [15] [12] [3] [24].

3. RESULTS AND DISCUSIONS

Progressing forefront of renewable energy studies gives light of optimism for enduring energy creation, distinctively within offshore territories. Following sections, it shall be shown the ensemble of expansive exerts and reviews excerpted from many scholarly-reviewed papers, mainly aiming at offshore wind, wave, and solar power mechanisms. The assembly of these outcomes does not solely mirror state and performance of such technologies but additionally highlights swift technical advancements, ecological ramifications, and monetary opportunities these frameworks include. The merged perceptions aspire to portray elaborate scenery of offshore renewable energy domain, showing advancement and possibility buttressing their place as keystones in future energy lattice. This delve into newest factual validations aims to reinforce comprehension on how each green technology functions within offshore scenario, interplay amongst diverse energy gathering methods, environmental elements needing handling, plus fiscal practicality that may be tapped.

We're studying offshore renewable energy because of the global need to move to cleaner, more sustainable energy in the face of climate change. Decarbonising, especially in the energy sector which is a big chunk of global emissions, is a key goal. As the land-based renewable energy capacity is nearing saturation, the marine environment offers a huge and largely untapped opportunity for growth. Researching offshore renewable energy technologies (wind, wave, solar) is important for innovation, cost reduction and minimisation of environmental impacts. The study is also important because we need technological advancements to harness these resources, we need to replace fossil fuels and there are big environmental and economic benefits and opportunities from offshore renewable energy. [18]

This section discusses the progress in offshore wind energy, the latest insights in wave energy conversion, the breakthroughs in floating solar PV systems and the environmental considerations that come with these. [4] [2] We want to capture the momentum that is driving the offshore renewable energy sector towards a more sustainable and economically viable future.

3.1. Offshore Wind Energy

Our extensive review revealed that offshore wind energy represents one of the most promising and rapidly advancing sectors in renewable energy technologies. Analysis indicates that offshore wind farms, especially those utilizing floating platforms, have seen significant growth in both technological sophistication and deployment scale. Floating wind farms have been recognized for their capacity to harness wind energy more effectively, with potential power densities reaching up to 57.5 MW/km^2, a substantial improvement over traditional fixed-bottom installations. [25] [26] This advancement is attributed to stronger, more consistent wind patterns offshore and the ability of floating platforms to be sited in deeper waters where winds are more abundant. [3]

Research has also underscored the reduced variability in power generation associated with floating wind farms—power variations have been predicted to decrease by approximately 68% in comparison to their land-based or fixed-bottom counterparts, leading to a more reliable energy output. This stability is crucial for integrating wind energy into the power grid and for ensuring a consistent supply to meet energy demands. [3]

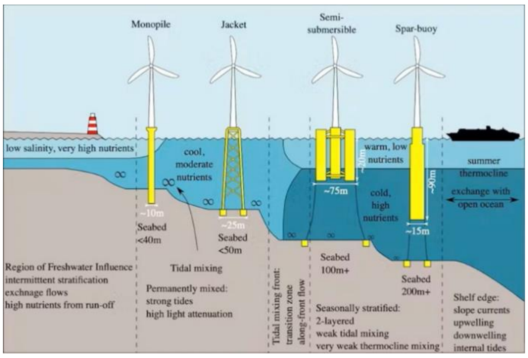

Figure 1 Even 'floating' wind turbines still have large underwater foundations to keep things stable.
Figure processed by the authors on the basis of information presented in [27] , Accesed on 23 June 2024

The deployment of cutting-edge technology like sensors and data analysis tools is making a significant impact in offshore wind farms. These gadgets identify maintenance issues early. This reduces downtime. Furthermore it enhances reliability. This is crucial for maintaining such projects profitably in the long haul [28] [29].

While the growth of offshore wind energy is promising, the sector faces notable challenges. These

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include installations and the necessity for robust designs to withstand harsh marine conditions. [30] [31] Nonetheless recent technological advancements and supportive policies bode well for this industry. It is poised to play a pivotal role in our sustainable energy future. [3]

Table 1.Comparative analysis of the advantages and disadvantages of using different types of renewable energy capture technologies

Type	Advantages	Disadvantages
Onshore Wind Turbines	Established and mature technology Lower installation and maintenance costs compared to offshore [3]	Potentially lower wind speeds than offshore Land use limitations and possible conflicts with residential areas
Offshore Wind Turbines	Access to higher and more consistent wind speeds Less visual and noise impact on populations [3]	Higher installation and maintenance costs due to marine operations Limited to shallower waters, usually up to 50 meters depth [3]
Floating Offshore Wind Turbines	Accessible for deployment in deep water areas beyond the limits of fixed-bottom turbines Reduced visual and acoustic impact due to distance from shore [3]	Still in the early stages of commercialization and can have higher costs Potentially higher maintenance challenges and costs due to dynamic marine environment [3]
Hybrid Systems	Diversification of energy sources leads to a more stable energy output Potential for combined efficiencies and reduced infrastructure costs [3]	Increased complexity in design and integration Likely higher initial research and development costs and need for advanced technology [3]

4.2. Wave Energy Conversion

The extraction of energy from ocean waves has shown remarkable progress. There is spectrum of wave energy converters undergoing advanced stages of development and testing. Our review uncovered that certain hybrid systems amalgamate offshore wind turbines with wave energy converters. These systems demonstrate the capacity to complement wind energy. They provide additional outputs ranging from 2 to 3 MW from wave energy on the same platform. This enhances overall system productivity. [12] For instance, the W2Power platform is designed to produce a total of 10 MW. Its wave energy component contributes a significant portion. [12]

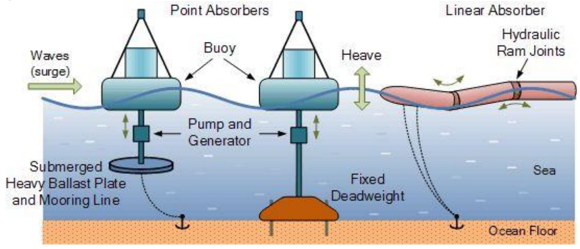

Figure 2 Offshore wave energy convertor. Figure processed by the authors on the basis of information presented in [32] , *Accessed on 11 May 2024*

Operational efficiency has also been greatly improved with these transducers; Studies have shown that hybrid systems, such as a spar buoy with integrated WEC, can significantly reduce movement stresses by up to 23%, thereby reducing maintenance requirements and extending the life of the platforms structural length increases. [12] Although promising, current wave energy conversion technologies face challenges such as the lack of long-term performance data and the need for a robust optimization strategy to fully harness, respected, wave energy potential calculated to be 100 kW/m average power at 1 -m wavefront [4] Methodology. These findings recommend a more focused and coordinated approach to R&D in wave energy conversion systems, making the most of the large and sustainable ocean energy

Based on the analyzes of different types of wave energy conversion, it is clear that both seasonal variation and site-specific wave energy characteristics significantly influence the potential electrical output, highlighting the importance of selection of consumption devices function appropriately and are installed to maximize energy harvesting emphasis. [33]

4.3. Solar Energy Harvesting

Solar energy harvesting, especially through floating photovoltaic systems, is an area of great interest in renewable energy. Studies show that FPVs can increase energy efficiency by 3-6% by using the cooling water. [3] When applied in water, significant water loss can also be prevented by evaporation. [3] These designs use non-toxic recyclable materials such as durable polyethylene, capable of operating over a wide

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temperature range, ensuring the longevity of FPV in a variety of climatic conditions [3]

In addition, economic analysis shows that FPV is a cost-effective alternative to conventional ground-based solar and floating wind power [3] These innovations provide sustainable development from small initial installations, such as a 20 kW system in Japan, to large scale prototypes such as a 40 MW project in China, demonstrating the scalability and application of this technology faster. [3]

While the current references mainly focus on the benefits of FPV technology, future research could examine FPV using other renewable energy sources, which could provide opportunities for energy generation systems the capacity and robustness have been improved ., n.d) Furthermore, developments in this area can influence innovative product design and contribute to informed decision making regarding the use of renewable energy .

Mixing FPVs with sea-based green power sources, like wind and water power, shows the broad plan we're using to make energy more stable and cover the world's energy needs better [34] [3]. As the rules change to help more use of green power [24], FPVs keep marking a big step in our aim for a clean and safe energy future. [2]

4.4. Environmental Impact Analysis

Looking into how green energy systems can harm or help our world is key for keeping our planet healthy. Floating solar panels show a lot of promise for doing good things for nature. For example, putting these panels on water can help keep the water cool by shading it. This is very important to keep water life safe [3] Also, placing them in the sea means we use less land, causing less harm to the earth. [15]

Moreover, shifting our energy sources to include power from the sea helps fight human-caused climate warming. These smart tech methods can cut down harmful gas releases by adding to the clean energy we get from land. [24] Combining different kinds like FPVs with sea wind plants can also make our green energy more dependable. This helps protect our environment by lowering the harm energy production does to it. [2]

The push for offshore renewables, such as wind and sun structures, isn't always handiest aligned with the decarbonisation goals of the shipping zone through mitigating maritime emissions [24], but is also instrumental in enjoyable broader global aims to reduce the impact of climate alternate, a task that poses significant risks to both humanity and biodiversity. [15] As the era develops, it's far imperative to recollect the operational- and renovation-associated effects on marine habitats, ensuring that the quest for cleanser electricity does no longer compromise the fitness of our oceans. [2]

In the end, FPVs and different offshore renewable strength structures are essential within the shift toward a lower carbon future, no longer simplest in terms of strength era performance however also in lowering the ecological footprint of electricity production, thereby contributing to the energy sector's alignment with environmental conservation and climate mitigation objectives. [35] [24]

Table 2. The impact of renewable energy capture technologies on the environment

Descriptors	Offshore wave energy	Offshore solar energy	Offshore wind energy
Ecosystem disruption	Can alter marine habitats and affect marine life due to underwater devices and mooring	Limited direct interaction with marine life; may affect water flow and temperature	May disrupt undersea life during installation; noise affects marine mammals. Creates artificial reefs
Visual Impact	Relatively low; structures mostly below waterline or minimally visible above surface.	Moderate impact depending on installation size and platform transparenc y.	Significant impact due to tall turbines visible from shore.
Noise Pollution	Underwater noise during installation and operation could affect marine life.	Generally low; occasional noise during maintenanc e.	Construction and operational noise affect marine life and shore activities.
Shipping Navigation	Navigation hazard if near shipping lane; requires careful siting.	Requires marking to avoid collisions; sited away from major shipping lanes.	Requires buffer zones, alters shipping routes; turbines visible to ships.
Fishing Activities	Could restrict fishing' may benefit fish populations as arficial reefs.	Limited fishing access; potential conflicts with fishing interests.	Limits fishing near turbines; provides new habitats and attracts fish.
Bird and Bat Fatalities	Low risk; devices mostly submerged.	Limited risk to birds; some waterbird collision risk, bats generally unaffected	Collision risk for birds and bats, lower impact compared to onshore turbines.
Habitat Creation	Creates new habitats around	Floating systems could offer	Turbine foundations create

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	structures	new substrates for marine organisms.	artificial reefs support marine biodiversity

This paragraph tries to synthesize environmental effect insights through interweaving facts from the provided references. [3] [15] [24] [2] However, the numbers and facts specially associated with environmental impacts are quite constrained within the given excerpts.

4.5. Comparative Analysis

The increasing pursuit of offshore renewable energy has brought offshore sun, wind, and wave electricity harvesting into sharp focus. When assessing the collective capability and fee efficiency of these systems, several research verify the capacity financial blessings. For instance, floating photovoltaic systems were determined to be less expensive than similar potential wind-based totally floating power units, with efficiencies further stepped forward due to the cooling effects of water increasing electric output by using three-6%. [3] Furthermore, the monetary feasibility of wave energy converters built on offshore farms has been deemed attractive, supplying competitive levelized expenses of strength, internet gift fee, and fees of sales returns. [3]

Offshore wind strength remains one of the most mature and broadly carried out varieties of marine-primarily based renewable power. The price of strength for such systems changed into suggested at 0.21 USD/kWh. [36] However, the growing intensity of water significantly influences the financial viability, with constant-backside foundations being commonly suitable as much as a intensity of 50 meters. [15] Beyond this, the capital prices rise extensively, doubtlessly making floating wind solutions extra economically sound in deeper waters. [37]

Wave energy harvesting is emerging as a promising contender, specially when included with different renewable assets like wind farms. [12] The precise factor of wave energy is that it offers a greater steady output than solar or wind because of the regularity of wave styles, yet it's far currently limited by using better capital prices and a want for endured technological refinement and long-time period information to enhance its monetary standing. [4]

Table 3. Classification of different types of renewable energy capture technologies

Type	Concept	Floating structure of Foundation	Country
Wind turbine	Retractable blade type wind turbines, Hemispherical oscillators	Floating (Spar platform, Tension leg platform, Semisubmersible platform), Bottom-fixed (Monopile, Gravity-based, Jacket types)	Various
Combine Wind and Wave Energy	Hydraulically coupled wind and offshore wave power systems	Floating platforms (Spar floater, Tension leg platform, Semisubmersible platform)	Various
Wave Energy Converter	Oscillating offshore column type, Wave-activated oscillating body type, Overtopping conversion type	Floating and Bottom-fixed structures	Various
Hybrid Wind and Wave Energy	W2Power, Combined Floating Wind turbine- Wave Energy Converter	Floating	Spain, USA
Wave Energy Converter	Motion suppression device for floating wind turbines	Floating	USA
Combined Wind and Wave Energy	Combined spartype floating wind turbine and floating wave energy converter (STC) system	Floating (Spar type)	Norway

In the end, even as FPVs exhibit decrease operational costs and enhanced performance, offshore wind energy advantages from set up generation and infrastructure. Wave power calls for similarly research for fee reduction but proposes a precious complementary aid. Decisions on the most fulfilling mix of those technology will depend on web page-unique elements, consisting of resource availability, water intensity, and environmental constraints [3] [15] [36] [12] [4]

5. CONCLUSIONS

In conclusion, the furnished documents spotlight the revolutionary improvements and diverse approaches to harvesting renewable energy in offshore settings around the arena. Technologies consisting of floating photovoltaic systems, offshore wind farms with each fixed and floating systems, and wave energy converters illustrate the dynamic and adaptive nature of this industry. Countries like Japan, California in the USA, Spain, and China had been pointed out as places wherein floating solar arrays had been applied, capitalizing on water bodies as valuable real estate for clean power generation. The integration of offshore wind and wave strength systems presents a ahead-questioning approach to maximizing power seize from marine environments. Notably, while precise information of all technology' deployment, including countries and foundation structures, aren't comprehensively designated in the documents, they set up a clean fashion of growing global interest and funding in offshore renewable power as a crucial part of our transition to a sustainable electricity destiny.

The obstacles present in the supplied documents center around a few key issues associated with offshore renewable electricity technologies:

1. **Technological Maturity:** Some offshore technologies, specifically wave electricity converters, are nevertheless inside the developmental or demonstration phase and feature now not reached the extent of industrial deployment that offshore wind has performed. They require similarly research and development to enhance value-performance and reliability. [12]
2. **Economic Feasibility:** The monetary viability of offshore strength structures can be a giant task. While floating photovoltaic structures display promise in phrases of value, the set up and upkeep of offshore wind generators can be expensive, especially in deeper waters wherein floating systems are necessary. [3] [12]
3. **Environmental Concerns:** There is a capability effect on marine ecosystems that desires to be cautiously managed. The creation and operation of offshore strength systems can disturb marine life. The long-term environmental effects need ongoing evaluation and consideration to make certain that the blessings of easy power do not come on the cost of marine health. [2]
4. **Energy Conversion Efficiency:** Current wave strength conversion generation has lower strength output compared to offshore wind turbines, with strength production from WECs normally being an order of significance smaller. [12]
5. **Infrastructure Challenges:** Offshore power structures require sturdy infrastructure for both installations and for transmitting electricity to onshore grids. This can involve complex engineering challenges, particularly in harsh marine environments. [3]
6. **Political and Financial Support:** Offshore renewable energy tasks regularly require full-size prematurely funding and supportive guidelines to incentivize development. Limited investment sources and converting regulatory landscapes can prevent development. [2]

These barriers propose that even as the ability for offshore renewable strength is sizable, there are sizeable hurdles that want to be addressed thru sustained studies, innovation, policy aid, and collaborative efforts between enterprise, governments, and communities.

The perspectives on offshore renewable energy mentioned within the provided documents are forward-searching and indicate some of pathways for improvement and integration into the energy blend of the future:

1. **Technological Advancement**: There's terrific ability for technological enhancements in offshore renewable power systems, inclusive of floating photovoltaics, offshore wind turbines, and wave electricity converters. As these technologies mature and scale up, they're likely to turn out to be more price-powerful and efficient. [3]
2. **Hybrid Systems**: Combining of multiple and different offshore renewable power such as solar, wind and wave electricity, should lead to greater constant strength output and system optimizations. These hybrid structures should combine electricity capture methods to maximize the use of marine area and decrease prices. [12]
3. **International Proliferation**: Different nations are committed to offshore renewable energy exploration and investment, worldwide. As technology and policy advances, it is likely that most of the regions in global spectrum will adapt these systems for an essential energy supply with safeguarding the greenhouse gas (GHG) emission. [3]
4. **Environmental and Economic Benefits**: When appropriately designed and managed, offshore renewable energy has the potential to provide considerable environmental advantages through the production of clean energy and reduced land utilization. From an economic perspective, these technologies can offer potential cost savings in the long term, particularly as their adoption and integration into global energy systems increase. [2]
5. **Policy and Regulatory Frameworks**: Persistent advancement of assisting policy alongside regulatory structures will hold crucial importance in the encouragement of offshore renewables. This encompasses inducements for investment, simplified processes for permits, in addition to global collaboration concerning standards as well as environmental optimal practices. [2]
6. **Grid Integration and Infrastructure**: When referring to infrastructure improvements, including advanced grid integration strategies and storage solutions, the focus must be to accommodate the variable nature of renewable energy and to transport electricity from remote offshore sites to onshore demand centers. [3]

The present investigation endeavors to conceptualize an avant-garde system for the harvesting of energy in offshore settings. This system amalgamates tripartite modalities of solar wave and wind energy

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conversion to effectuate the generation of electricity. The centerpiece of the proposed system is an aquatically ambulant platform. The platform is augmented comprehensively with photovoltaic panels. An intricate assemblage of generators is also included. All are conjoined through an elaborate nexus of transmission conduits. This facilitates a coherent and uninterrupted flow of electrical energy to terrestrial destinations. Instrumental to the operational integrity of this maritime energy apparatus is array of sophisticated environmental instrumentation. These instruments are tasked with the continuous appraisal of critical environmental metrics. Such metrics include the intensity of solar radiation. They also include the velocity of wind currents. Additionally, the amplitude of oceanic undulations is measured. This scholarly endeavor accentuates the principles of sustainability and operational efficiency. These principles are intended to navigate the multifaceted intricacies and prospects concomitant with the domain of maritime energy extraction.

Figure 3 Personal design, proiection of an offshore harvesting barge (wind energy, solar energy, wave)

The burgeoning imperative to expand renewable energy portfolio has stimulated heightened interest in the exploration of offshore energy sources. These sources have the potential to drastically augment the global renewable energy capacity. [38-40] Offshore set-ups, encompassing the vast expanse of seas and oceans. These offer a veritable treasure trove of renewable energy resources. These include wind wave and solar energy.

Overall, the perspectives from these documents. These recognize significant untapped potential in offshore renewable energy. They advocate for ongoing efforts in research policy and cross-sector collaboration. These initiatives aim to fully realize the benefits of these energy sources for a sustainable future.

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BEYOND THE HORIZON: FUTURE TECHNOLOGIES TRANSFORMING MARITIME NAVIGATION

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Abstract : The shipping industry is constantly evolving to meet today's demands and challenges. This article explores how innovations and trends in shipping are influencing the efficiency, sustainability and competitiveness of this vital sector of the global economy. Analysing technological transformations and emerging practices, the paper reveals how new technologies and cross-company collaborations are shaping the future of the maritime industry. The example of the BYD Explorer fleet, the first Ro-Ro vessel specialised in transporting electric cars, underlines the adaptability and innovation in response to the current needs of the automotive industry and sustainability requirements. At the same time, the collaboration between MOL and Bearing, which has led to the development of advanced solutions based on artificial intelligence, demonstrates the positive impact of innovation in optimising maritime operations.

Key words : artificial intelligence , competitiveness , efficiency , emerging technologies , globalisation , innovation, ports , shipping industry, sustainability.

1. INTRODUCTION

In a world of constant transformation, the shipping industry is constantly adapting and innovating to meet modern demands and challenges. In this context, emerging technologies and current trends are leading to a revolution in shipping, influencing not only the efficiency and safety but also the sustainability of this vital sector of the global economy. This article explores these innovations in depth, looking at how they are redefining the way ships move, how port operations are managed and how environmental issues are handled. Through a magnified perspective, we discover how these transformations are helping to shape a more efficient, sustainable and interconnected future within the maritime industry.

The purpose of research is to analyse and highlight the impact of current innovations and trends in shipping on the efficiency, sustainability and competitiveness of this vital sector of the global economy. By exploring new technologies, practices and collaborations between companies, the paper aims to provide a deeper understanding of how the maritime industry is adapting to the demands and challenges of the modern world and how these changes influence the global economy and the environment.

The research methodology involves analysis of current trends in shipping, case studies, collection and analysis of relevant data, and assessment of the impact and future prospects of the identified innovations. This approach provides an in-depth and comprehensive understanding of industry developments and future directions for the development of technologies and practices in shipping.

2. RESEARCHES AND INTERPRETATIONS

The transport industry is certainly undergoing a profound transformation, adapting to the new demands and challenges of the modern world. One of the most notable trends is the increasing demand for autonomous operations, digitisation and sustainability.

In terms of autonomy, we are seeing a proliferation of technologies that allow operation without direct human intervention. For example, drones, robots and driverless trucks are increasingly present in the transport landscape, facilitating autonomous last-mile deliveries. This not only improves efficiency and speed, but can also reduce the costs and risks associated with human intervention.

On the other hand, digitisation has become a key element in optimising the entire transport chain, from planning and management to monitoring and tracking of deliveries. Emerging technologies such as artificial intelligence, the Internet of Things (IoT) and block chain are increasingly integrated into transport systems to improve visibility, efficiency and security.

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In terms of sustainability, there is an emphasis on reducing the negative environmental impact of transport. A major solution in this respect is electrification, which allows a shift from fossil fuel vehicles to electric or other clean energy vehicles. This change not only reduces carbon emissions and other pollutants, but can also help increase energy efficiency and reduce dependence on non-renewable resources.

Figure 1 illustrates that around three quarters of the European Union's total international trade and its trade with non-EU countries is carried by sea [1].

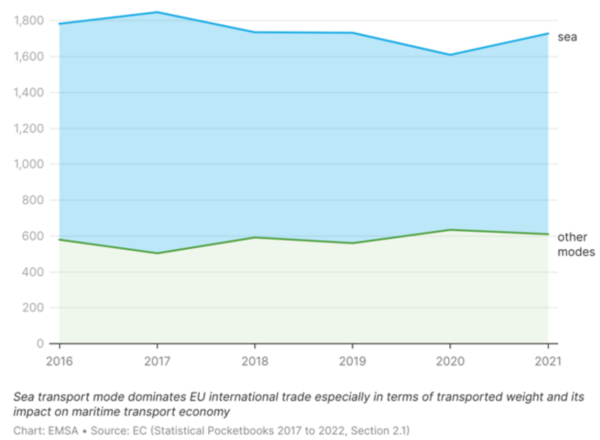

Figure 1 EU external total merchandise imports and exports in million tonnes from 2017 to 2021 [1]

With 77% of Europe's external trade and 35% of the total value of trade between EU Member States transported by sea, maritime transport is a key link in the international supply chain. This underlines the vital importance of the maritime industry in maintaining trade flows and ensuring economic connectivity between regions and countries.

Figure 2 shows the number of passengers embarking and disembarking at all EU ports over the period 2007-2022 [2], [3].

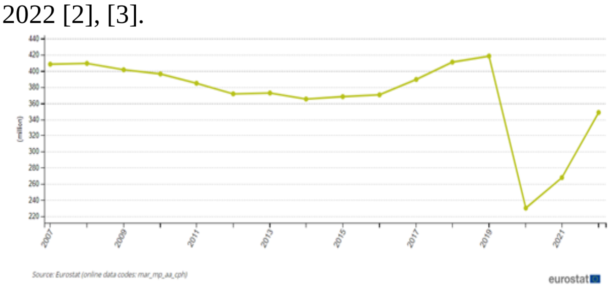

Figure 2 Seaborne passengers embarked and disembarked in all ports, EU, 2007-2022 [2],[3]

There is a significant decrease in the number of passengers in 2020, when the number of passengers was 230 million compared to 420 million in the previous year. This decrease can mainly be attributed to the restrictions imposed by the COVID-19 pandemic and social distancing measures that have severely affected the transport industry. However, in the following year, 2021, passenger numbers increased slightly to 270 millions, indicating a beginning of recovery in the industry. This positive trend continued in 2022, when passenger numbers increased to 350 millions. Therefore, a gradual recovery of maritime passenger activity after the negative impact of the pandemic is observed.

2.1 *Interpretations of data:*

Even with a decline in shipping activity in 2020 due to the effects of the COVID-19 pandemic, the sector is expected to grow strongly in the coming decades.

This growth is driven by a number of factors, including increased demand for primary resources and containerised shipping. In an increasingly globalised world, where international trade and interconnectivity are vital for national economies and global prosperity, shipping remains an important driver for development and economic growth.

2.2 *The adaptation of the maritime industry to the new demands of sustainability and advanced technology:*

In addition, the adaptation of the maritime industry to the new demands of sustainability and advanced technology is helping to strengthen its position in the international supply chain. Implementing environmentally friendly practices and innovative technologies in shipping not only helps to protect the environment, but can also support the efficiency and competitiveness of the entire supply chain.

Thus, the shipping industry is not only an essential component of the global economy, but also an important catalyst for progress and sustainable development in the 21st century. It is essential that governments, international organisations and industry players work together to promote safe, efficient and sustainable shipping that serves the current and future economic needs of our interconnected world.

Known for manufacturing electric cars, BYD Company Limited or BYD is a Chinese multinational conglomerate based in Shenzhen, Guangdong province. Founded by Wang Chuanfu in February 1995, the company brings a new perspective to the shipping industry. Given the growing demand for its cars, BYD made the decision to develop its own port to facilitate trade. To meet demand, the company invested in building a maritime fleet tailored to its needs.

Currently, BYD owns one vessel and has plans to purchase 7 more.

This ambitious venture's estimated total cost was nearly 5 billion yuan (approximately 700 million USD).With an impressive capacity to carry 7000 cars, these vessels are tailored to the company's specific requirements, including advanced on-board fire monitoring and warning systems. Specialised equipment enables rapid response to any fire, ensuring safe and efficient transport.

2.3 New standard in shipping:

The ship, officially named BYD Explorer 1, represents a new standard in shipping. As the world's first Ro-Ro vessel specialised in transporting electric cars, it offers an innovative solution to the needs of today's automotive industry.

At 200 metres long and 38 metres wide, the BYD Explorer 1 is designed for a cruising speed of 18.5 knots. Advanced propulsion systems, including a generator connected to a propeller, ensure efficient and sustainable operation of the vessel. It can operate predominantly on liquefied natural gas (LNG), minimising emissions and environmental impact.

Although building a ship takes time, BYD has found alternative solutions to meet immediate demand. Through strategic partnerships and adaptability, the company has been able to develop its own fleet and strengthen its position in the global market.

Future Ro-Ro ships built for BYD will be even larger, with a capacity of 7,700 cars. With these initiatives, BYD aims to become a major player in shipping, helping to increase exports and promote electric vehicles worldwide.

The use of shipping and its adaptation to consumer requirements are crucial for the efficiency and sustainability of global transport. The example of the BYD Explorer maritime fleet underlines the importance of adaptability in the shipping industry, highlighting the need to respond to market demands and promote innovation for a more sustainable future.

Another example that requires our attention is the collaboration between Mitsui O.S.K. Lines, Ltd. (MOL) and Bearing, Inc.

The year 2021 marked an important milestone in the collaboration between Mitsui O.S.K. Lines, Ltd. (MOL), a global leader in shipping, and Bearing, Inc. an innovative AI technology company in Silicon Valley. The expansion of their partnership initiated in 2019 demonstrated the power of innovation in transforming the maritime industry.

The main aim of the partnership was to optimise shipping efficiency. By combining the maritime expertise of Mitsui O.S.K. Lines (MOL) with Bearing's state-of-the-art AI-based infrastructure, a number of innovative products were developed. A prime example is the AI-powered Intelligent Routing Engine, which provides optimised routing recommendations for each voyage. This system automatically analyses multiple potential routes and evaluates them based on factors such as fuel consumption, emissions and weather conditions.

Bearing technology, based on highly accurate vessel performance models, provides state-of-the-art forecasting of key metrics such as fuel consumption. This valuable information enables MOL to make more operationally efficient decisions, reducing costs and improving sustainability.

The collaboration between MOL and Bearing is an outstanding example of how innovation can transform an industry. MOL's reputation as a technology leader in shipping, combined with Bearing's AI expertise, has led to the creation of innovative solutions that have a significant impact on the efficiency, sustainability and profitability of maritime operations.

2.4 Other significant results

In addition to the Intelligent Routing Engine, the partnership has generated other significant results:

- Development of advanced marine weather forecasting systems
- Optimising port operations
- Improving navigation safety
- Reducing greenhouse gas emissions

The partnership between MOL and Bearing demonstrates the enormous potential for innovation in the maritime industry. As companies continue to invest in AI-based solutions and other advanced technologies, we can expect to see even more significant transformations in the coming years.

Mitsui O.S.K. Lines and Bearing provide an inspiring example of innovative collaboration that is propelling the maritime industry towards a more efficient, sustainable and prosperous future.

3. CONCLUSIONS

The shipping industry is in the midst of an accelerating transformation and adapting to new demands and challenges is essential to maintain competitiveness and sustainability. Recent examples, such as the BYD Explorer fleet and the collaboration between MOL and Bearing, highlight the main directions of this transformation.

The BYD Explorer fleet is an outstanding example of adapting to changes in the automotive industry and sustainability requirements. By building the first Ro-Ro vessel dedicated to transporting electric cars, BYD affirms its commitment to innovation and environmental protection. Its capacity to carry 7000 cars and the use of advanced technologies to secure the transport demonstrate a focused effort towards a more efficient and environmentally friendly maritime operation.

On the other hand, the collaboration between MOL and Bearing, two leaders in the fields of shipping and AI technology, highlights the power of synergy in optimizing maritime operations. By developing innovative AI-based solutions such as the Intelligent Routing Engine, this collaboration demonstrates how technology can improve efficiency, safety and sustainability in shipping.

Overall, these examples underline the need for innovation and collaboration in the shipping industry to respond to market demands and contribute to sustainable development. Investments in technology and strategic partnerships are essential to build a competitive and sustainable future in this vital industry for the global economy.

4. ACKNOWLEDGMENTS

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SHORT INTRODUCTION ON PRESENT DESIGN AND TRENDS REGARDING ENERGY EFFICIENCY IMPROVEMENT ON LARGE CRUDE OIL TANKERS

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Abstract: This paper covers some aspects regarding present technology used in large crude oil carriers design and operation, as well as requirements regarding energy management on board. Obviously, due to complexity of such subject, there cannot be an exhaustive presentation. It is intended as a mere starting point for further discussion and research regarding possibilities to improve vessel's general energy efficiency, including ways of using non-conventional and renewable energy, with due regard to specific trading routes involving large oil tankers. Some practical figures achieved typically on a Very Large Crude Oil Carriers engaged in international voyages are presented. A brief explanation on Energy Efficiency Index (EEI) and Carbon Conversion Factors (CF), as accepted by IMO, is also included. Work may be continued with further theoretical research in energy efficiency improvement on board such vessels. The article is structured in five parts: Introduction, Main Particulars of Large Tankers, Oil Tankers Outfitting, Energy Management Plan and Conclusion.

Key words: Carbon, Efficiency, Energy, Management, Oil Tanker, VLCC

1. INTRODUCTION

Some maritime disasters resulting in large oil spills and public outrage, like Torrey Canyon (1967), Amoco Cadiz (1978), Exxon Valdez (1989), Prestige (2002), have triggered significant changes as of building, maintenance, inspection and operation of oil tankers, especially the larger ones.
New regulatory requirements have been introduced as follows: [9]; [10]:

- Double skin in the way of cargo oil and bunker oil tanks.
- Limitation of each individual cargo oil tank volume with the aim of reducing most probable discharge in case of a marine casualty involving bulkhead(s) rupture and loss of hull integrity.
- Requirements in regard of corrosion protection of the ship's structure, especially in the cargo oil tanks and water ballast tanks area.
- New rules for structural design and material certification.
- Requirements for structural inspection during vessel's operational lifetime in order to verify its hull and structural integrity.
- Promoting best practices in regard of vessel's operation.
- Requirements for thermal engines fitted and fuels used in order to reduce release to atmosphere / environment of carbon monoxide, carbon dioxide, nitrogen and sulphur oxides, etc.
- Improved equipment and installations with the aim of avoiding release to atmosphere of volatile organic compounds, hydrogen sulphide and ozone depleting substances.
- Ballast Water Treatment in order to avoid transfer of marine invasive species.

In line with above, Industry is encouraged to explore new methods and research directions in regard of fossil fuels reduction, usage of alternative technologies and power sources, as well as improvement of ships general energy efficiency in order to reduce overall environmental footprint.

With reference to energy efficiency improvement, following topics are taken into account:

- Hull optimization in order to reduce drag.
- Energy economy by use of miscellaneous devices designed to increase propeller efficiency, reduce of hull drag, etc.
- Usage of renewable energy (wave, wind, solar).
- Structural optimisation and overall lightweight reduction by using modern design and new materials.
- New design of the entire outfit on board in order to increase energy efficiency (main and auxiliary engines, residual heat economisers,

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cargo and ballast handling systems, refrigeration, air conditioning, hydraulic power packs, etc.
- Energy Efficiency Management during operation.
- Route Management and Optimization.

2. MAIN PARTICULARS OF LARGE CRUDE OIL CARRIERS (SUEZMAX AND VLCC)

Design and outfitting of oil tankers are based on regulatory, technical and commercial requirements. Regulatory and technical requirements are established by IMO, Maritime Government Administrations, Classification Societies, etc. Commercial requirements may vary with the needs of actors involved such as Ship-owners, Oil Majors, Traders, Shipyards, etc.

Most common large tankers engaged in oil transportation on medium and long distances are typically named Suezmax and VLCC.

Suezmax

Suezmaxes are designed to comply with Suez Canal restrictions in regard of maximum transit draft in fully laden condition. They are generally used for medium and long haul of crude oil, less often residual fuel oil and very occasionally refined petroleum products. Their typical carrying capacity is about 1,000,000 barrels. Usual dimensions: Length Over All = 270 meters; Beam = 48 meters, Summer DWT = 150,000 – 180,000 MT

Figure 1 Suezmax vessel at Kakinada Anchorage, India. (*Source: Author's personal archive*).

Very large crude carrier (VLCC)

VLCC's are large tankers typically engaged on long and very long distances transportation of crude oil, very occasionally fuel oil. Their typical carrying capacity is about 2,000,000 barrels. Usual dimensions: Length Over All = 340 meters; Beam = 58-60 meters, Summer DWT = 300,000 MT (approximately). Normally this kind of vessel cannot access most majority of the world ports, except certain Oil Terminals specially designed for this size.

Figure 2 VLCC during Ship To Ship crude oil transfer operation to a Panamax size vessel in the Gulf of Tonkin (*Source: Author's personal archive*).

General layout of an Oil Tanker.

An Oil Tanker typical compartmentation consists of:
- Cargo Oil Tanks Compartment
- Water Ballast Tanks Compartment
- Cargo & Ballast Pumps Compartment (Pump Room)
- Engine Room
- Steering Gear Room
- Navigational Bridge
- Cargo & Ballast Control Compartment (Cargo Control Room)
- Living and Social Spaces Compartment.

As an example, below are given main particulars of a VLCC. Worth to mention that other larger or smaller size Oil Tankers fitted with centrifugal Cargo and Ballast Pumps (Panamax, Aframax, Suezmax, ULCC) have a similar design and outfitting.

Ship's Particulars:
- IMO No.: 9312511
- LOA: 332,848M
- LBP: 320,00M
- Beam: 58,00M
- Design Height: 31,00M
- Draught (summer): 22,70M
- DWT (summer): 307284
- ME Power: 29400KW@76rpm
- Max Speed: 16.58 Kts
- Building Shipyard: Dalian, China
- Year of Build: 2007

3. BRIEF PRESENTATION ON OIL TANKERS OUTFITTING

In terms of their role in the operation of the ship, installations on board an oil tanker may be classified as main propulsion, steering, power generating installations, support installations and specific operating installations (cargo, ballast, inert gas systems).

3.1 *Propulsion plant*

The propulsion installation is intended to provide mechanical energy to the movement of the ship in a longitudinal direction. In modern oil tankers, it consists of the main slow diesel engine, shaft and propeller. The propeller force depends on a series of parameters: diameter – D, number of blades – Z, tilt of the propeller axis, step – p, propeller speed – n, etc.
Propulsion force in the direction of the axle [6]:

$$F = \rho n^2 D^4 (1 - t) K_F \left(J, \frac{p}{D}\right), \quad (1)$$

where:

t - push reduction fraction due to the influence of the hull;
J - thruster advance (v – axial speed, w – scale factor).

$$J = \frac{v(1-w)}{nD} \quad , \quad (2)$$

p/D – pitch coefficient.
During operation, a lateral force and a moment of torsion occur:

$$M = \rho n^2 D^5 K_M \left(J, \frac{p}{D}\right). \quad (3)$$

3.2 *Steering system*

Steering gear is designed to keep the ship in the direction of travel, as well as to ensure the necessary course changes by means of a rudder driven by an electro-hydraulic system. The rudder behaves like a small wing that generates a force and a moment of yaw that allows the ship to steer. On large oil tankers it is used normally a hydraulic actuated, semi-balanced rudder.
The approximate expressions of the steering force and the moment are [6]:

$$F_y = C_y \frac{\rho v^2}{2} S; \quad (4)$$

$$M_Z = C_y \frac{\rho v^2}{2} S \frac{L}{2}, \quad (5)$$

where: S – rudder area, L – ship's length, C_y – the lift coefficient.

3.3 *Support installations*

- *The power-generating facility* has the role of providing the necessary energy for the operation of all the electrical equipment on board.
- *The electricity distribution installation* has the role of ensuring the transmission of electricity to consumers through distribution panels, command/control panels and electrical circuits. Electrical circuits can be force circuits for three-phase current that supply large consumers (electric motors), remote control circuits or domestic circuits (lighting, single-phase current sockets, etc.).
- *The steam production plant* has the role of providing the necessary steam to heat and maintain the heavy fuel at the temperatures necessary for transfer, purification and combustion, to operate the steam turbines, to heat the cargo compartments, to heat the social and residential compartments, to protect some installations exposed to frost in winter. On board large tankers this plant is oversized due to main pumps fitted on cargo and ballast systems are normally high capacity centrifugal pumps driven by steam turbines.
- *The installation for the generation of inert gas and ventilation of cargo tanks* is designed to ensure that an atmosphere that does not allow combustion is maintained inside tanks and cargo piping, due to its too low oxygen content (less than 8%), as well as an atmosphere slightly positive from the atmospheric one (approximately 200-1400 mm water column), in order to prevent the infiltration of atmospheric air into the inert atmosphere in the event of possible leaks of the installation.

3.4 *Cargo and ballast systems*

On board oil tankers these systems have the role of handling liquid oil cargo and water ballast, respectively. They generally consist of single stage centrifugal pumps, piston pumps and ejectors. Typically, cargo system on a VLCC is fitted with 3 cargo oil pumps with a capacity of about 5500 cubic meters / hr each, 2 cargo stripping ejectors of about 500 cu meters / hr each and 1 steam driven reciprocating piston pump with a capacity of about 150 cubic meters / hour, while ballast system has 2 water ballast pumps with a capacity in the range of 3000 cubic meters / hr each and 2 ballast stripping ejectors of about 300 cu m/hr each. It is a common practice that such centrifugal pumps are lined up to work in parallel.

4. SHIP'S ENERGY EFFICIENCY PLAN

In July 2011, IMO adopted the concept of The Energy Efficiency Index of Ships (EEDI), which regulates the minimum energy efficiency criteria of new ships built after 2013. It is determined according to

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carbon dioxide emissions per ton-mile of cargo transported. Through the global adoption of EEDI, it was

aimed at increasing the energy efficiency of ships by 10-30% between 2013 and 2025. The improvement of the Energy Efficiency Index of Ships has induced the need to develop a Management Plan regarding the energy efficiency of the ship.

The Energy Efficiency Management Plan is prepared in accordance with MARPOL Annex VI, Regulation 22.2[10] and IMO MEPC Resolution. 282(70) / 2016 – Guide for the elaboration of the Ship's Energy Efficiency Management Plan [10].

The plan consists of two parts:

- Part I – Establishing a mechanism to improve the energy efficiency during the operation of the ship.

- Part II – Collecting fuel consumption data.

Methods to improve energy efficiency - IMO MEPC. 282(70) are [10]:
- Optimal voyage planning - IMO Resolution A.893 (21) [10]
- Hydro meteorological assistance of navigation
- Speed optimization for timely arrival in the destination port
- Optimization of the power used for propulsion
- Optimization of the ship's manoeuvre.
- Optimization of the amount of ballast used
- Maintenance of the hull
- Maintenance of the main propulsion system
- Recovery of waste heat
- Improving fleet management
- Improvement of operational procedures for cargo handling.
- Energy management on board the ship
- Optimization of the type of fuel used to reduce CO_2 emissions
- Optimization of computer-aided consumption
- Use of renewable energy sources (wind, solar, photovoltaic).
- Use of wind-assisted propulsion.

The Ship Energy Efficiency Management Plan (SEEMP) is a measure which establishes a mechanism of energy efficiency improvement on board ships at acceptable costs. It is designed to assist ship's operators in monitoring energetic performance of every individual ship and of entire fleet as a whole, over a certain period, introducing the concept of Energy Efficiency Operational Indicator, (EEOI). EEOI is intended to assist operators in monitoring energy efficiency and encourage improvement of energetic performance due to better conditions in vessel's operation such as: better voyage planning, hull cleaning & propeller polishing, fitting of improved residual heat recovery equipment, etc.

Such SEEMP do encourage owners and operators to consider new technologies and practices for overall energy performance improvement on ships.

According to the IMO MEPC Resolution. 282(70) / 2016 [10], the calculation of the Energy Efficiency Index (EEI) is conceptually based on the formula:

$$EEI = ECO2 / (M \times D). \quad (6)$$

where CO_2 emissions (ECO_2) are expressed in grams, M is the transported mass expressed in metric tonnes and D is the transport distance expressed in Nautical Miles.

CO_2 emissions (ECO_2) over an hour (h) may also be expressed as the product of the amount of fuel consumed in an hour (FCH) and the carbon dioxide (CF) conversion factor, i.e. the amount of CO_2 resulting from the combustion of a unit of fuel

$$ECO_2 \times h = FCH \times CF. \quad (7)$$

Fuel consumption per hour (FCH) can also be expressed as Machine Power (MP) multiplied by the specific fuel consumption (SC) expressed in grams per kilowatt hour

$$FCH = MP \times SC. \quad (8)$$

Replacing fuel consumption per hour (FCH) in (9) results in:

$$ECO2 = MP \times SC \times CF. \quad (9)$$

Replacing CO_2 emissions (ECO_2) in (8) results in:

$$EEI = (MP \times SC \times CF \times h) / (M \times D). \quad (10)$$

In other words:

$$EEI = (MP \times SC \times CF) / (M \times V) \quad [g\ CO_2 / (Tone \times Mm)], \quad (11)$$

where V is the speed of the vessel expressed in knots.

If it is conventionally considered that the useful mass carried in tonnes M is equal to the nominal deadweight of the vessel, then it can be written in the following form:

$$EEI = (MP \times SC \times CF) / (DWT \times V) \ [g\ CO_2 / (TDW \times Nm)]. \quad (12)$$

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As can be seen from eq.(11) and (12), a ship is overall the more energy efficient as the Energy Efficiency Indicator (Index) is lower.

Another approach of leading international experts (Rightship Organisation, Carbon War Room) is to calculate the energy efficiency of an existing vessel using the existing data on the consumptions of a particular vessel.

The EEOI (Energy Efficiency Operational Index) is based on the IMO's methodology for calculating the EEDI (Energy Efficiency Design Index). The main difference between EEDI and EEOI relates to the way of collecting consumption data. While EEDI data is made available by classification societies and refers to a new vessel at the time of commissioning, the data for the calculation of the EEOI are calculated retroactively for existing vessels using the data available from ship-owners, charterers, shipyards, etc.

However, the actual formula for calculating the EEOI for an existing vessel has not been made public by the initiators. The differences refer to the calculation of the fuel consumption (theoretical or real) and to the transport capacity (constructive or actually used DWT of the vessels).

In conclusion, the above approaches lead to the calculation of carbon emissions in grams per tonne and nautical mile (g/TNm) and are related to the transport distance and the quantity of cargo transported.

For reference, the carbon dioxide conversion factors (CF) for different types of fuels are given in below Table 1:

Table 1. The CF (t-CO_2/t-Fuel) certain value at each type of fuels.[10]

Fuel Type	Reference	Carbon content	CF (MT CO2/MT Fuel
Diesel Oil	ISO 8217	0.8744	3.206
Light Fuel Oil	ISO 8217	0.8594	3.151
Heavy Fuel Oil	ISO 8217	0.8493	3.114
LPG	Propane	0.8182	3.000
LPG	Butane	0.8264	3.030
LNG		0.7500	2.750
Methanol		0.3750	1.375
Ethanol		0.5217	1.913

Source: IMO, Ship Energy Efficiency Regulations and Related Guidelines, Module 2

Proceeding on sea voyages

- The sea passage of the ship is carried out at an economic speed, consistent with the planned operation date.
- The navigation route is chosen by the Master, based on the available hydro-meteorological information, usually in consultation with a specialized shore based meteorological office appointed by the shipping company.
- It is decided whether some maintenance and repair operations are required, as well as supply of fuels and materials.
- Cargo tanks preparation is made for the next cargo, depending on the cargo previously transported.

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Table 2. Fuel Oil consumption in MT/24 Hrs on a VLCC (307284 TDW), build in 2007, in laden condition with a mean draft of 21.0 M, in good weather ≤ BF 5. Total daily consumption figures rounded to the nearest MT, for more clarity.

Speed (Kts)	ME Power (Kw)	Rpm	Load % MCR	Specific Consumption FO for ME (g/kwh)	ME FO Consumption (MT / 24 hrs)	AE FO Consumption (MT / 24 hrs)	Total Cons. (MT / 24 hrs)
8	7391	49,4	25,1%	200,0	35,5	5,5	41
8,5	8015	50,8	27,2%	199,5	38,4	5,5	44
9	8684	52,2	29,5%	198,9	41,5	5,0	46
9,5	9405	53,6	32,0%	198,4	44,8	5,0	50
10	10183	55,1	34,6%	197,8	48,3	4,5	53
10,5	11023	56,6	37,5%	197,2	52,2	4,5	57
11	11934	58,2	40,6%	196,6	56,3	3,5	60
11,5	12921	59,8	43,9%	196,1	60,8	3,5	64
12	13993	61,4	47,6%	195,5	65,7	3,5	69
12,5	15160	63,1	51,5%	195,0	70,9	3,5	74
13	16431	64,9	55,8%	194,5	76,7	3,5	80
13,5	17817	66,7	60,6%	194,1	83,0	3,5	86
14	19331	68,6	65,7%	193,8	89,9	3,5	93
14,5	20986	70,5	71,3%	193,6	97,5	3,5	101
15	22797	72,5	77,5%	193,6	105,9	3,5	109
15,5	24781	74,6	84,2%	193,8	115,2	3,5	119
16	26957	76,8	91,6%	194,3	125,7	3,5	129

Table 3. Fuel Oil consumption in MT/24 Hrs on VLCC (307284 TDW), build in 2007, in ballast condition with a mean draft of 9.5 M, in good weather ≤ BF 5. Total daily consumption figures rounded to the nearest MT, for more clarity.

Speed (Kts)	ME Power (Kw)	Rpm	Load % MCR	Specific Consumption FO for ME (g/kwh)	ME FO Consumption (MT / 24 hrs)	AE FO Consumption (MT / 24 hrs)	Total Cons. (MT / 24 hrs)
8	4542	42,0	15,4%	202,8	22,1	7,5	30
8,5	5010	43,5	17,0%	202,3	24,3	7,0	31
9	5528	44,9	18,8%	201,8	26,8	6,5	33
9,5	6103	46,5	20,7%	201,2	29,5	6,0	35
10	6739	48,1	22,9%	200,6	32,4	5,5	38
10,5	7443	49,7	25,3%	200,0	35,7	5,0	41
11	8224	51,4	28,0%	199,3	39,3	5,0	44
11,5	9089	53,2	30,9%	198,6	43,3	4,5	48
12	10047	55,1	34,1%	197,9	47,7	4,5	52
12,5	11108	57,0	37,8%	197,2	52,6	3,5	56
13	12283	59,0	41,7%	196,4	57,9	3,5	61
13,5	13586	61,0	46,2%	195,7	63,8	3,5	67
14	15028	63,1	51,1%	195,0	70,3	3,5	74
14,5	16626	65,3	56,5%	194,4	77,6	3,5	81
15	18397	67,6	62,5%	193,9	85,6	3,5	89
15,5	20358	70,0	69,2%	193,6	94,6	3,5	98
16	22530	72,5	76,6%	193,5	104,7	3,5	108
16,5	24937	75,0	84,8%	193,8	116,0	3,5	119
17	27603	77,6	93,8%	194,5	128,8	3,5	132

Source for Tables 2 & 3: Vessel's shipyard documentation and on board records.

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5. CONCLUSION

Design, building and operation of oil tankers are based upon several decades' old technology and are subject to regulatory, technical, financial and commercial constraints. Despite ongoing technological progress which led to improved electronically controlled engines, better specific fuel consumption, stricter environmental standards, etc. a major breakthrough in regard of vessel's design, operation, materials, installations, cargo and ballast (sea water) handling has not been achieved.

Energy efficiency is a paramount characteristics of an oil tanker from the regulatory, specific equipment, operation, and commercial point of view. Most of the specific operations like loading, discharging, and cargo oil tanks preparation result in release to atmosphere of certain quantities of hydrocarbons and hydrogen sulphide, instead of same being utilised to generate additional energy on board or at shore based facilities. Moreover, the larger the tanker, the larger the quantities involved.

During ballast passages, oil tankers need to carry a quantity of sea water ballast amounting to about 30 % of their nominal transport capacity (Deadweight), which require additional energy consumption. Moreover, such ballast needs to be loaded, treated and discharged using supplementary amount of energy. Not to say that such installations needed to handle the ballast water are an added weight to the lightship.

Research regarding energy efficiency improvement cannot and should not be limited to improved propulsion and on board energy generation, as an example. A real breakthrough can be achieved only by an interdisciplinary approach in regard of design, construction, operation, maintenance and recycling of the vessels at the end of their operational lifetime. Energy efficiency question should not be limited only to how much energy would be needed to transfer this much cargo from point A to point B over these much Nautical Miles. In a larger view question may be raised on how much energy would be necessary to build, carry a certain total amount of cargo over a certain total sea distance during a certain scheduled operational life time and then recycle the vessel.

Following points may be of relevance when attempting to follow above quest:

- Using of new materials for hull, superstructures and installation building in order to reduce lightweight.
- Radical changes in ship's design which will permit substantial reduction or total elimination of sea water ballast carriage needs. This may reduce the size / eliminate ballast water handling installation, further reducing vessel's lightweight.
- Investigating the possibility of operating the vessel in non-displacement or partly displacement mode when in light condition.
- Using of renewable / non-conventional energy for main propulsion, to boost main propulsion, to generate additional energy for on board installations or as a mean of emergency propulsion / steering in extraordinary circumstances.
- Using of residual cargo vapours to generate additional power
- Using of variable geometry elements in building the hulls and superstructures.

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THE ENERGETIC TRANSITION OF SNP

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Abstract **:** The paper "THE ENERGETIC TRANSITION OF SNP" synthesizes the green strategies that the company must apply, according to the European Green Pact, in order to avoid the expansion of environmental pollution.

Regarding strategic strategies and objectives, the paper will focus on presenting strategic directions such as the approach of the sulphur dioxide emission reduction strategy and the digital transformation strategy. As for the environmental policy, it follows the principles of precaution, prevention and correction of pollution at source and on the principle „ the polluter pays”.

Also, within the paper we will analyse some graphs and statistics on the financial performance of OMV PETROM, highlighting the success that the company has in recent years precisely due to green investments!

Key words : green energy, energy transition, green investments, sustainability,

1. INTRODUCTION

We are at a crucial moment for the transformation of the energy sector, with the ongoing energy crisis highlighting the central role that biomass can play to ensure energy security, at the same time contributing substantially to the EU's climate and carbon neutrality objectives.

OMV PETROM is the largest company on the energy market in Romania, listed on the Bucharest Stock Exchange, having as object of activity the oil and gas industry. Performs activities in various areas such as exploration, production, marketing, refining and petrochemicals.

The transformation for a low-carbon future is one of the European green pact strategies that reflect the company's growth plans and its commitment to the energy transition. This strategy will transform OMV PETROM into an integrated, low-carbon energy company.

2. ENERGY TRANSITIONS

2.1 European Environmental Policy:

Energy production and consumption account for more than 75% of EU greenhouse gas emissions. In order to achieve our climate objectives for 2030 and climate neutrality by 2050, it is therefore imperative that we decarbonise the EU's energy system.

The European green agreement focuses on three aspects of the clean energy transition to reduce greenhouse gas emissions and improve our quality of life:

1. Ensuring a secure and affordable energy supply in the EU;

2. Developing a fully integrated, connected and digitised EU energy market;

3. Prioritising energy efficiency, improving the overall energy performance of our buildings and developing an energy sector predominantly based on renewable energy sources.

Romania will receive over 16 million euros from the EU for two developed projects: 432 charging stations for electric cars.

2.2 Environmental strategies of OMV PETROM :

The OMV PETROM project will be subsidised by 15 million euros and aims to introduce 408 recharging points of 150 kW in 98 existing locations dedicated to light commercial vehicles. Each recharging station will be equipped with a network connection of at least 600 kV.

Until the year 2030, OMV PETROM aims to have a significant impact on the transition to a lower carbon business and will reduce the intensity of emissions in all business segments.

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The strategy of economic growth regarding environmental degradation is achieved by promoting eco-efficiency and interpreting high standards of environmental protection as a challenge to innovation, creating new markets and business opportunities.

The strategy on waste from the oil industry that cannot be stored indefinitely requires OMV to be based on the best available technologies.

3. EVOLUTION OF THE ENERGY MARKET IN ROMANIA

3.1 Evolution on the market of OMV PETROM

In Figure 1 we observe the evolution of expenses and revenues recorded by OMV PETROM in the period 2018-2022, according to the data published on the company's website [1], but also of the Bucharest Stock Exchange, as well, where the company is listed.

Figure 1 Evolution of expenditure and revenue [1]

On the chart we see an accelerated growth of both indicators starting with 2020, the value of the revenues increasing from 18544 millions RON (in 2020) to 66230 millions RON (in 2022), and the amount of expenses increased exponentially from 17040 millions RON (in 2020, 1 Euro= 4.778 RON).) to 54303 millions RON (in 2022, 1 Euro= 4.93 RON).

In Figure 2 we observe the evolution of profit and turnover, the main indicators of the performance of financial profitability, recorded in the period 2018-2022 at OMV PETROM [2], [3], [4].

Figure 2 Evolution of Turnover and Profit [2]

Thus, in the light of the above graph, we observe a stability of the profit values between 2018 and 2021 and an exponential growth from 2021 to the end of the analysed period (from 2658 millions RON in 2021(1 Euro= 4.92 RON) to 10287 millions RON in 2022)[5], [6], [7]. The same thing (growth) we notice in the case of turnover, only here, only, there was a decrease between 2019 and 2020 (most likely due to the outbreak of the pandemic) followed by an increase in the following year (2021), the recorded value being superior to that of 2019 (from 19793 millions RON in 2019 at 23586 millions RON in 2021), and at the end of the analysed period followed an exponential growth of CA, similar in percentage to that of profit (the turnover value reaching 55939 millions RON in 2022).

Despite the decrease in the number of employees observed in Figure 3, SA OMV PETROM recorded an increase in labour productivity during the same analysis period (2018-2022) [8], [9].

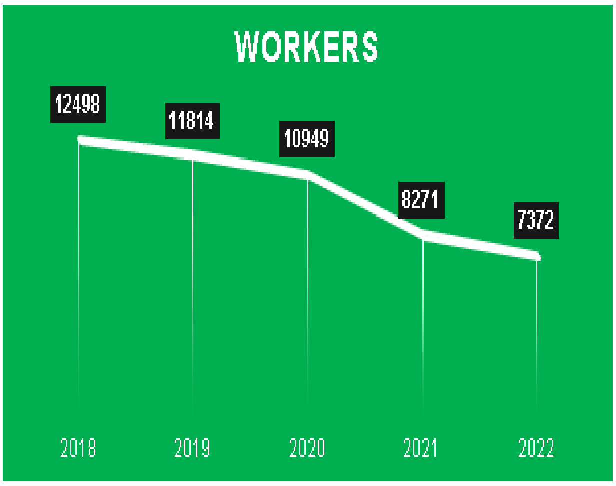

Figure 3 Evolution of the number of workers at OMV PETROM [1]

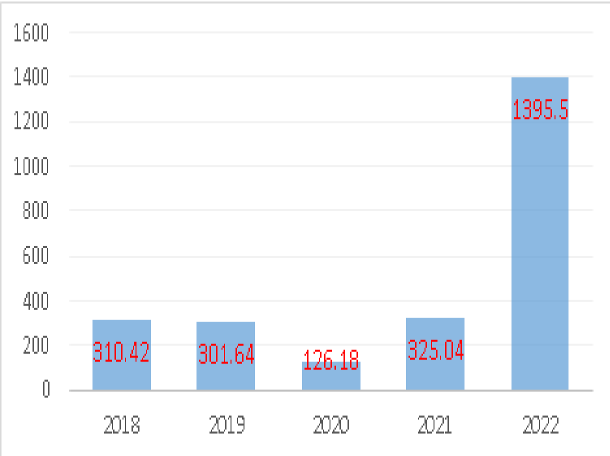

Figure 4 Productivity Evolution at OMV PETTROM [6]

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In Figure 4, however, we see a drop in productivity between 2018 and 2020, followed by not very significant growth in 2021, most likely due to the pandemic you throw when employees worked more online and that proved statistically more productive for the company, he said, so the OMV continued the restructuring until the end of the period so in 2022 the increase in labour productivity was exponential, but throughout this period the company continued to invest massively and this fact helps to the values recorded statistics of the above-mentioned performance indicator [6], [7], [9], [10].

3.2 Green investments of OMV PETROM

OMV PETROM approved the „Romania Efficient" program that promotes energy efficiency at national level through public information campaigns. The project has two major dimensions: on the one hand, there is the part of information, education and public awareness, and on the other hand, the execution of renovation works. [6], [9]

With a contribution of 5.7 million Euros, the "Romania planting program for tomorrow" is the largest privately funded planting initiative in Romania. Over 2,000,000 seedlings were planted on 450 hectares in the period 2020-2023.

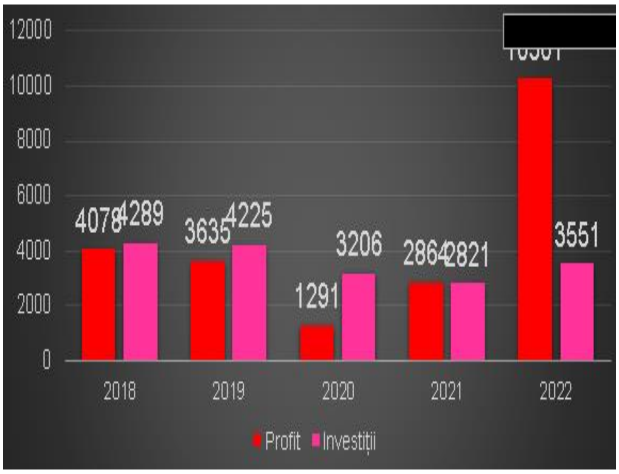

Figure 5 Profit-investment relationship [1]

In Figure 5 we can see the relationship between the investments made by OMV PETROM in the period 2018-2022 and the profit recorded in the same period [4], [5]. Following the chart above, we can see the value of investments superior to that of profit in the period 2018-2020, while starting with 2021, the profit exceeds the investment so we can say that the investment effect is a significant one given the value of the profit recorded at the end of the period analysed, we can say that, which is superior to investment (10301 millions RON - profit versus 3551 millions RON - the investment).

4. CONCLUSIONS

OMV PETROM, in order to remain a market leader, must analyse the expectations of its customers, the way in which its own performance and the degree of customer satisfaction are perceived.

OMV PETROM should continue to invest in the development and implementation of cleaner and more efficient technologies.

The company could work with non-governmental organisations and local communities to identify environmental issues and develop appropriate solutions.

5. ACKNOWLEDGMENTS

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CHARACTERIZATION OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS IN AREAS WITH FISHING POTENTIAL

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Abstract: In the present study, the physico-chemical quality of the water in the Midia coastal area, the Tasaul Lake and the Siutghiol Lake water bodies were analyzed, as integrated sites in the territory of the North Dobrogea FLAG. This study allows establishing the state of favourability of the aquatic ecosystem, focusing on the chlorophyll content as the basis of the trophic level. The premise of a stable ecosystem induces the possibility of developing natural fish resources. An essential attribute in the context of preserving natural heritage and increasing the attractiveness for fishing activities, is the need to evaluate the qualitative and quantitative profile of the phytoplankton and, respectively, the eutrophication indicators. If aquaculture activities will be developed in the analyzed areas in the future, they could increase the economic value of the Romanian sector of the Black Sea. The biological analyzes of the water quality are the basis of the substantiation of some methods of its determination and evaluation. Thus, testing the concentration of chlorophyll, the classes of algae and the photosynthetic activity, are useful for the evaluation of eutrophication in the aquatic environment, but also for the evaluation of productivity in the surface waters studied. At the same time, the determination and evaluation of the physical and chemical parameters of water quality allowed the realization of some correlations with the structure of the biota. In this sense, the analysis methods are based on the use of modern equipment based on real time (in situ) determinations.
Key words: eutrophication, phytoplankton, chlorophyll concentration, sea water, fresh water

1. INTRODUCTION

The restoration of aquatic habitats is essential for sustaining biodiversity and improving fishing conditions. At the national level there are a number of strategies and actions that can improve conditions for fishing, ensuring a healthy ecosystem for future generations. These actions can be implemented at the local and/or regional level, of which we mention a few more important ones: restoring wetlands that can improve habitat for many species and provide a breeding environment for fish; control of invasive species, an essential aspect for maintaining the ecological balance; the implementation of fishing restricted areas that can allow fish populations to regenerate and thrive; monitoring and research that can help identify problems and adapt restoration strategies.

At the national, european and global level there are numerous organizations and associations that focus on the conservation of aquatic resources, the promotion of sustainable fishing and the support of fishing communities. One of the most notable local initiatives in the Dobrogea region is the Dobrogea Nord Local Group Association. The mission of FLAG Dobrogea Nord is to ensure a sustainable development of the fishing activity in the North of Constanța county, based on sustainable activities. Regarding the demand on the fish market, the new statistics show that only 12% of the national consumption of fish products is covered by domestic production, thus there is a commercial need that could be covered in a larger proportion by the domestic market. It is known that at present the aquatic resources are not exploited to their real potential, and the fisheries facilities in the marine area (fishing nets, mariculture) want to be modernized and expanded in order to sustainably diversify the types of resource exploitation (including species currently less exploited, for example, clams). Thus, an analysis of the quality of waters with potential for fish in the northern area of Constanța county, will allow the construction of potentially polluted areas and respectively with better water quality, suitable for increasing the capture of fish resources and/or the development of mariculture.

There are a number of aspects regarding the quality of waters with potential fish, of which we mention:

- identification of polluted areas
- evaluation of water quality parameters
- identifying and protecting areas with good water quality

- developing best practice strategies to minimize the impact of pollution and maximize fish catches
- effective collaboration between the authorities, the scientific community and local communities to develop plans for the conservation of aquatic resources
- supporting the innovation of new technologies based on digital monitoring systems to make the use of aquatic resources more efficient
- facilitating investments in mariculture to create a sustainable infrastructure
- public education, which is essential to ensure a sustainable management of these ecosystems with potential fish.

Since aquaculture is a large consumer of water, it is preferable to develop it where there are natural resources. However, the big problem that arises is the quality of the aquatic environment which must fulfill required standards in order to function as an environment for the growth and development of the fish resource. It is well known that the quality of natural surface waters, especially lakes, is constantly threatened by pollution through various factors [1], [2], [3].

Among the most serious problems is poor water quality in terms of biological and physico-chemical characteristics. Parameters such as pH, alkalinity, hardness are not toxic to fish directly, but can influence other parameters, sometimes in quite complex ways, increasing the negative effect produced on the fishes. Other physico-chemical parameters such as dissolved oxygen, temperature, ammonia, depending on their value/concentration, can lead to fish death [4]. The main objective of the study is to develop an analysis of the physico-chemical and biological parameters in order to identify the polluting agents that can affect the development of fish resources.

This article contains the analyzes results of the water quality parameters carried out in two seasons in 2024: vernal season and aestival season, following the changes produces among the chemical and biological parameters (temperature increase, dissolved oxygen decrease, phytoplankton development, etc).

Freshwater or marine phytoplankton is the base of the trophic chain in an aquatic ecosystem, with rapid development and a strong ability to adapt to environmental conditions [5]. In this sudy we evaluated the concentration of phytoplankton, as an essential parameter in the proper development of fish resources, by measuring chlorophyll-a from different types of algae found in three sites (lacustrine areas and coastal area in the North of Constanța county).

2. MATERIALS AND METHODS

2.1 Physical-chemical analysed parameters

Variations in physico-chemical parameters have a particularly large impact on the growth and development of fish populations, starting with factors such as temperature, alkalinity, hardness, pH and ending with the concentration of dissolved oxygen, ammonium ions, phosphate, etc [6]. The presence in the water of heavy metals and/or detergents leads to serious imbalances in the metabolic processes of aquatic organisms.

The following physical parameters:

- temperature,
- pH,
- electrical conductivity and
- turbidity

were measured in situ with a waterproof meter wits GPS function (HI-9829 multiparameter) at 1meter depth.

For the dissolved oxygen analyses, the water samples were collected at 1meter depth in Winkler bottles and analysed by iodometric method.

For analysing the other chemical parameters, the samples were collected at 1meter depth in polypropylene containers and kept away from light, prior to analyses.

The parameters analyzed in the laboratory were:

- dissolved oxygen,
- biochemical oxygen demand (BOD_5),
- alkalinity
- total hardness
- cadmium, lead
- ammonium and orto-phosphate ions.

Dissolved oxygen, BOD_5, alkalinity and hardness were analysed using titrimetric methods and specific reagents. For BOD_5, the samples were kept five days at 20^oC in a cooler incubator FOC 120I Connect.

Alkalinity was analysed by titration with hydrochloric acid and hardness by titration with ethylenediaminetetraacetic acid disodium salt dihydrate (EDTA).

Cadmium, lead, ammonium and orto-phosphate ions were measured spectrophotometrically with *SpectroquantPharo 300.* Before the spectrophotometric determinations, samples were filtered to remove particulate matter.

Cd determination is based on the Cd ions reaction with 1-(4-nitrophenyl)-3-(4-phenylazophenyl) triazene and lead determination is based on the Pb(II) ions reaction with 4-(2′-pyridylazo) resorcinol. Both analyses take place in alkaline solution, with the formation of a red complex which is measured spectrophotometrically

$N–NH_4^+$- the method is based on the ammonium ions reaction with hypochlorite, in alkaline solution, in order to form a monochloramine. This in turn reacts with a substituted phenol to form a blue indophenol derivate that is determined spectrophotometrically in VIS.

$P–PO_4^{-3}$ - the method is based on the orthophosphate ions reaction with molybdate ions, in acid medium, in order to form a phosphomolybdic complex. This complex is reduced with ascorbic acid to a blue coloured compound which is measured spectrophotometrically [7]

All the spectrophotometrically determinations used are in accordance with ISO 8466-1 and DIN 38402 A51.

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2.2 Evaluation of chlorophyll content

The study of the main groups of primary producers is based on the determination of chlorophyll concentration. Real-time (in situ) measurement technologies are preferred in marine and freshwater ecological monitoring [8], [9]. Since the distribution of phytoplankton in the water is at different depths, the use of equipment for rapid measurement of the fluorescence profile is necessary. The requirements mentioned above are satisfied by the FluoroProbe III analyzer which allows the real-time recording at a depth of up to 100 m, of different classes of algae. The FluoroProbe is switched on by connecting Pins 5 and 6 of the connectors by using the power supply, the converter cable or the auto-start-plug. In situ measurement is done by connecting the auto-start-plug device to the analyser. Thus, the auto-start-plug is used to measure without a PC. Previously, the FluoroProbe needs to be configured accordingly using the measuring cable / RS485 which allows the settings of parameters. Only the parameters marked with the green symbol can be changed. The charge state is indicated by the green color of the LED.

The FluoroProbe III analyzer uses six LEDs for fluorescence excitation for algae differentiation, these LEDs emit light with six fixed wavelengths (370nm, 470nm, 525nm, 570nm, 590nm and 610nm). Due to the fact that algae of the same division contain a similar quantity and quality of photosynthetic pigments, their fluorescence excitation spectrum (with a fixed emission wavelength at 680nm) is significant. Thus, it is possible to differentiate divisions of algae by their fluorescence excitation spectrum. In addition to this, other fluorescing matter (for example, yellow substances) is detected to enhance the accuracy.

The fluorescence signal for each LED is taken and averaged during a certain measurement time. The algae classes detected by the analyser are *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae* (*Diatoms*), *Cryptophyceae*.

These measured spectra are retained in the analyzer's memory and can later be sent to a PC computer. The content of algal classes in the sample can thus be analyzed. The measuring results are stored in files in the FluoroProbe. Starting the measurement starts a new file. The maximum file size is 1,754 datasets.

The chlorophyll analyser has integrated two additional temperature and pressure sensors and to calibrate the temperature sensors and the pressure sensor is used the “Sensor” item from the software.

The depth is calculated direct from the pressure.

depth [m] = (pressure [bar] - air-pressure [bar]) * 10 [m/bar]

The analyses are performed at different depths for each site in order to capture important vertical features. The measurements were made in two seasons: vernal season (April) and aestival season (July), which corresponds to a development of phytoplankton. The three analyzed sites are: Midia Navodari Black Sea coastal area, Tasaul Lake and Siutghiol Lake [10].

3. RESULTS AND DISCUSSIONS

3.1 physical-chemical parameters

In table 1 are presented the results of the physical-chemical analyses carried out in the months of April and July for the water samples taken from specified sites.

Table 1. The average values of the physical-chemical investigated parameters

Parameters	**Siutghiol Lake**		**Tasaul Lake**		**Midia Navodari**	
	April	July	April	July	April	July
Temperature (°C)	19.62	27.81	19.54	27.73	18.07	26.72
Turbidity (FNU)	17.9	47.5	19.8	95.2	1.4	1.7
pH	8.99	9.12	9.21	9.31	8.49	8.34
Conductivity (mS/cm)	3.55	3.53	4.24	4.49	23.38	29.64
Alkalinity (mval/l)	6.67	6.48	8.43	8.23	3.14	2.94
Hardness (mval/l)	10.4	10.3	10.3	10.64	44.77	46.62
DO (mg/l)	11.49	8.02	10.05	18.38	12.04	8.33
BOD5 (mg/l)	2.33	3.77	3.54	5.82	1.81	2.55
Cd (mg/l)	0.01	0.012	0.011	0.016	0.006	0.005
Pb (mg/l)	0.03	0.05	0.05	0.04	-	-
$N\text{-}NH_4^+$ (mg/l)	0.32	0.33	0.70	0.67	0.02	0.03
$P\text{-}PO_4^{3-}$ (mg/l)	0.06	0.12	0.07	0.41	0.02	0.02

The evaluation of the physical-chemical parameters of the water quality is important because the aquatic environment must ensure the optimal conditions for the growth and development of the fish.

Temperature influences the growth and development of fish only if it is at the limit of fish tolerance or registers sudden variations. In addition to the fact that it influences metabolism, temperature is closely correlated with the speed of chemical reactions and with the amount of dissolved oxygen [11].

In the present research study, the temperature of all collected samples registered normal values, in correlation with the season and the sampling site. Thus, the lakes water temperature was around 20 °C in April

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and 28 ^{o}C in July, and the sea water temperature was around 18 ^{o}C in April and 27 ^{o}C in July.

The penetration of light into the water is prevented, in general, by the presence of clay particles, which leads to high turbidity and/or planktonic organisms [6]. As a result, the production of oxygen by the aquatic plants is slowed down, which can decrease fish productivity.

The highest turbidity was registered for Tasaul Lake water in July, 95.2 FNU, almost five time higher than in April, 19.8 FNU. For the sea water, the turbidity was very low, around 1.5 FNU.

The pH, which is interdependent with alkalinity, hardness and water content in carbon dioxide, has a profound effect on fish health, the toxicity of ammonia and oxygen availability.

For optimal growth of most freshwater fish species, desirable pH range is 6.5-9.0, but for the most marine animals, a pH range between 7.5 - 8.5 is ideal [1], [11]. Slightly alkaline pH is preferable in waters, as heavy metals are removed by carbonate or bicarbonate precipitates [12].

From this point of view, for the analyzed period of time, it can be said that the sea water fulfills the conditions for the optimal development of the fish resource, because the recorded pH was not higher than 8.5. For Siutghiol and Tasaul lakes water, the analysed samples had close pH values between 8.99 and 9.31, which are higher that limit imposed by Order 161/2006 for surface water (8.5) [13].

Alkalinity and hardness are relatively stable, but can change over time, usually weeks to months, depending on the pH or mineral content of waters. For Siutghiol Lake water, alkalinity was around 6.5 mval/l, for Tasaul Lake water, a bit higher, around 8.2 and for sea water around 3. For each analyzed site, the alkalinity values were close in time, with a difference of at most 0.5 units less from the vernal to the summer season.

The most common components of alkalinity are carbonates, bicarbonates, hydroxides and phosphates. Alkalinity due to carbonate and bicarbonate ions and hardness in surface waters, are produced through the interactions of water, limestone and CO_2. Calcium and magnesium are essential in the biological processes of fish (scale and bone formation, and some metabolic reactions). Fish can absorb calcium and magnesium from the water or from food [6].

Like the alkalinity, the hardness was almost constant over time for all three analyzed sites, recording values around 10 mval/l for lakes water and 45 mval/l for sea water.

Dissolved oxygen plays an important role for the survival, growth and behaviour of aquatic organisms, a dissolved oxygen level of more than 5 mg/l being essential to support good fish production [14], [15].

The most important sources of oxygen in water are photosynthesis by phytoplankton and atmospheric air. The solubility of oxygen in water is low and the level of dissolved oxygen in water depends on temperature, salinity and pressure variations [6], [11].

In vernal season, the concentration of dissolved oxygen in water for all analyzed sites was between 10 and 12 mg/l. Once the temperature increased, the concentration of dissolved oxygen decreased, being around 8 mg/l in the aestival season, with the exception of Tasaul Lake where a very high value of dissolved oxygen was recorded (18.38 mg/l). The high amount of dissolved oxygen in July in Tasaul Lake can be correlated with a high primary production with algal blooms.

The biochemical oxygen demand (CBO_5) represents the amount of total dissolved oxygen utilized by microorganisms for the biodegradation of organic matters present in water, during five days.

The analyses of the biochemical oxygen demand show variation in time and from one site to another. For all the analyzed sites, it can be said that CBO_5 recorded lower values in April and higher values in July. The lowest values were recorded for Black Sea water (1.81 mg/l in April and 2.55 mg/l in July) and the highest values for Tasaul Lake water (3.54 mg/l in April and 5.82 mg/l in July).

Ammonia is a dissolved gas present naturally in surface waters, being the major end product in the breakdown of proteins in fish. Ammonia also results from bacterial decomposition of organic matter such as dead algae and aquatic plants. Assimilation of ammonia by plankton algae is important in reducing the amount of ammonia coming in contact with fish [6].

Total ammonia nitrogen (TAN) is composed of nontoxic (ionized) ammonia (NH_4^+) and toxic (un-ionized) ammonia (NH_3). The percent of total ammonia nitrogen in toxic form increases as the temperature and pH of the water increase. Ammonia is removed by bacteria that convert it into nitrate, process facilitated by maintaining a pH between 7-9 and a temperature between 24-29° C.

The $N\text{-}NH_4^+$ content was quite varied between the sampling sites, but almost constant for the same site in the two seasons in which the samples were taken. The lower values were registered for sea water (0.02 mg/l in April and 0.03 mg/l in July) and the highest for Tasaul Lake water (0.7 mg/l in April and 0.67 mg/l in July).

From the point of view of $N\text{-}NH_4^+$ content, we can say that the sea water and the Siutghiol Lake water are situated in the first class of quality (the concentrations of $N\text{-}NH_4^+$ were lower than 0.4 mg/l) and the Tasaul Lake water is situated in quality class II (the concentrations of $N\text{-}NH_4^+$ were close to 0.8 mg/l), according to Order 161/2006 [13].

Phosphorus is an essential plant nutrient, almost all of the inorganic phosphorus in water being in the form of ortho-phosphate (PO_4^{3-}). This ion is generally present in surface water as attached to living or dead particulate matter [6].

Generally, in natural surface waters, phosphate ion occurs in concentrations less than 0.1 mg/l. Phosphate is considered harmless if we ignore its role in promoting the growth of undesired algae in the water. The

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recommended range of values for the phosphate ion concentration is 0.05-0.3 mg/l and when phosphate concentration exceeds 0.3 mg/l, can lead to eutrophication [11].

For the water of the Black Sea, the content in ortho-phosphate ions was very low (0.02 mg/l) and identical for the two seasons in which the analyses were performed. In vernal season, for the lakes water, the concentration of ortho-phosphate ions was almost the same (0.06 mg/l for Siutgiol Lake and 0.07 mg/l for Tasaul Lake), but in July for the water of the Siutgiol Lake the value was twice as high and for the water of the Tasaul Lake four times as high.

In accordance with Order 161/2006, the results for ortho-phosphate ion concentration place the waters analyzed in first quality class (maximum 0.1 mg/l), except the water from Tasaul Lake in July, when the registered value place it in quality class III (0.4 mg/l) [13].

One of the water important contaminants is the heavy metal pollution. The presence of heavy metals in surface waters raises important problems related, among other things, to their accumulation in fish and the diseases they cause. Some metals, such as arsenic, cadmium, lead, mercury are non-essential elements and are highly toxic for organisms. Adverse effects of cadmium on fish include reproductive problems, high blood pressure and kidney/liver dysfunction and lead bioaccumulation in fish primarily affects the liver, spleen, kidney and gills [16], [17].

For all samples analyzed, regardless of the season, the concentration of cadmium ions was not higher than 0.02 mg/l and the concentration of lead ions was between 0.03 mg/l and 0.05 mg/l. Thus, from the point of view of the content of these two metals, the analyzed waters can be classified in the first quality class, according to Order 161/2006 [13].

3.2 Biological parameters

The long-term development of activities for the analysis of the quality of the pelagic environment allows highlighting the perspectives of growth and fish exploitation, as well as the critical points faced by fishing activities in the Black Sea and lake areas. The representative groups of phytoplankton are analyzed - green algae, cyanobacteria, diatoms and cryptophytes (including the yellow substance), with direct influence on the quality of aquatic life in the bordering area of fishing activities (marine site - Midia Navodari area and lacustrine sites - Tasaul Lake and Siutghiol Lake).

It is known that the dynamics of phytoplankton is influenced by the geographical location of the water bodies as well as the type of water basin. In the temperate zone there is a great difference between the summer and winter seasons. Regardless of the type of water body, in the most cases there is a general model of the dynamics of phytoplankton populations. In this context, we chose to carry out an analysis of phytoplankton dynamics in different ecological successions, based on modern measurements to identify the concentration of chlorophyll in water.

Figures 1 and 2 show the average chlorophyll concentrations recorded in the four groups of phytoplankton, during the two seasons - vernal and aestival.

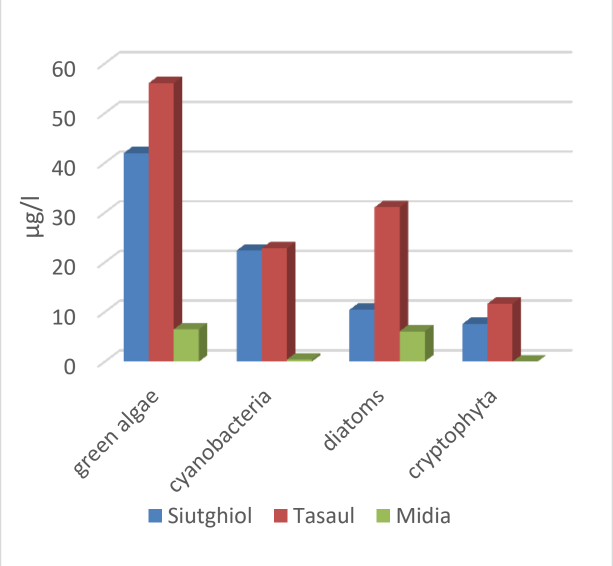

Figure 1 Average chlorophyll concentration in the representative phytoplankton groups (vernal season)

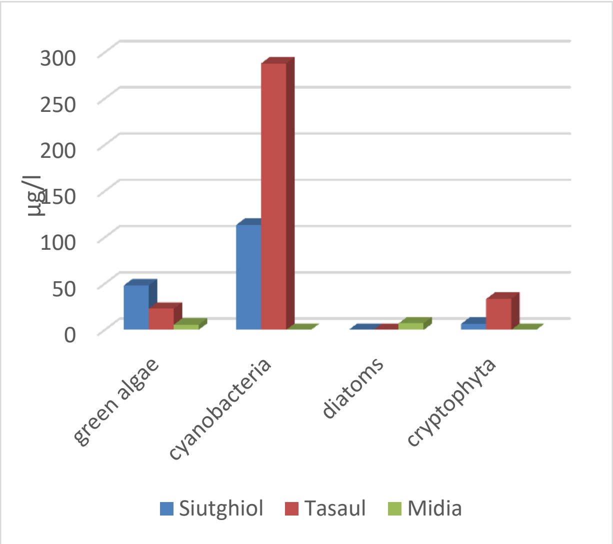

Figure 2 Average chlorophyll concentration in the representative phytoplankton groups (aestival season)

If we draw a parallel between the two seasons, some remarkable differences can be observed, namely:

- in the Siutghiol Lake the group of cyanobacteria recorded a fivefold increase in the average concentration of chlorophyll between the two seasons and, respectively, a reduction of the group of diatoms that was present in the vernal season (10.44 µg/l) followed by its absence in July. Also, the green algae group

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maintained its chlorophyll concentration unchanged in the two seasons. In the Siutghiol Lake for the April, the largest percentage was recorded by the group of green algae 50.95%, followed by cyanobacteria 27.15%; instead, for July, cyanobacteria were dominant with 67.53%, followed by green algae (28.52%).

- in the Tasaul Lake, the cyanobacteria group recorded a thirteen-fold increase in the average chlorophyll concentration between the two seasons, respectively a reduction in the diatom group that was present in the vernal season (13.06 µg/l) followed by its absence in July. Another significant change occurs in the case of green algae, where the concentration of chlorophyll decreased from one season to another (2.5 times). In Tasaul Lake in April, green algae are predominant (46.11%), diatoms, the second group, representing 25.55% of the total phytoplankton; but in July the qualitative structure changes substantially, cyanobacteria dominating (83.64%) followed by green algae (6.63%).

- for the Midia Navodari coastal site, we note the absence of the Cryptophyta group in both seasons. In the Midia area, the group of cyanobacteria was not recorded in July. Diatoms had similar chlorophyll concentrations in the Midia area in the two seasons, registering a slight increase in July compared to April (6.09 µg/l vernal season, 7.18 µg/l aestival season). In the Midia area, the group of green algae dominates (50.07%), followed by diatoms 46.9% for April; respectively, in July the weight of phytoplankton is reversed, dominating diatoms (56.88%) followed by green algae (43.19%).

The difference can be noted regarding the type of water body, the value of the concentration of chlorophyll in green algae being between 4-9 times higher in lakes, compared to the coastal marine environment.

During the vernal season, when spring changes occur in the water column as the wind drives the lake's water volume, these changes mark the beginning of the ecological succession, in which small species that have a high growth rate dominate. During this period, samples can be taken during spring algal blooms, which occur as a result of sudden variations in available nutrients in conjunction with rising water temperatures. At the opposite pole, in the aestival season there is an intensification of phytoplankton development, in summer the dominant species show larger sizes, with a reduced development capacity, which are able to conserve biomass and nutrients. In lake waters, the vernal and estival season represents the period of algal explosions with cyanobacteria, an aspect found in the samples from Siutghiol and Tasaul. Algal blooms generate a series of inconveniences from an aesthetic, ecological and even human health point of view.

In Tasaul Lake in the vernal season, a high correlation was found between the water depth (for measurements up to a maximum depth of 2.3 m) and the concentrations of green algae and cyanobacteria, with R^2=0.76 (fig. 3) and R^2=0.67 (fig. 4), respectively. For diatom and Cryptophyta groups in Tasaul Lake, the correlations with water depth were moderate, R^2=0.55 and R^2=0.42 respectively. A weak correlation of the chlorophyll concentrations of different types of algae with water depth was found for Siutghiol Lake ($0.15<R^2<0.38$), for a maximum depth of 2.0 m, and Midia Navodari Black Sea coastal area ($0.02<R^2<0.14$), for measurements up to a maximum depth of 2.6 m.

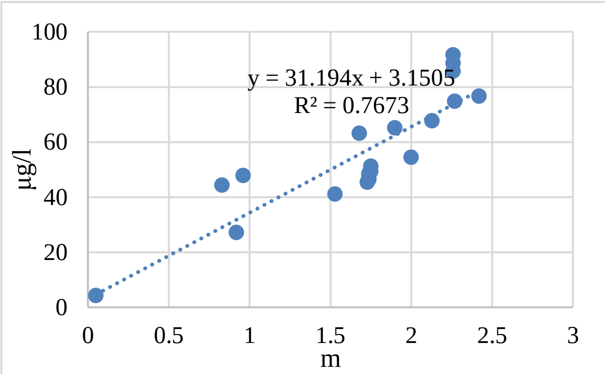

Figure 3 Tasaul Lake-April. Chlorophyll-a concentration in green algae depending on the water depth

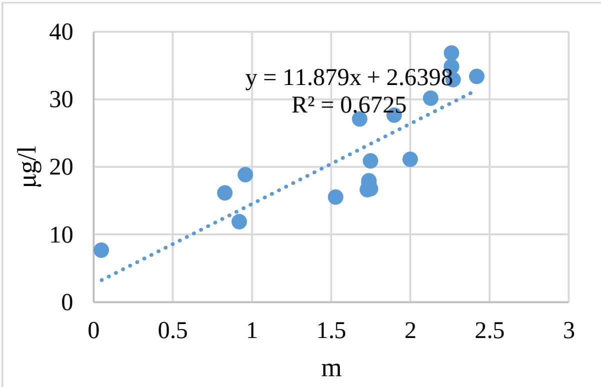

Figure 4 Tasaul Lake - April. Chlorophyll-a concentration in cyanobacteria depending on the water depth

In the summer season, a good and very good correlation was recorded between the water depth and the concentration of green algae in Tasaul Lake (fig. 5) and Midia Navodari Black Sea coastal area (fig. 6). In these locations, the July measurements regarding the concentration of the other types of algae, showed a very weak and weak correlation with depth (R^2=0.11 for Tasaul, and $0.04<R^2<0.28$ for Midia Navodari). In Siutghiol Lake, the correlation between algae concentration and water depth was very weak ($R^2<0.09$).

For most measurements, both in April and July, the highest algal densities were found around 1.5 m depth.

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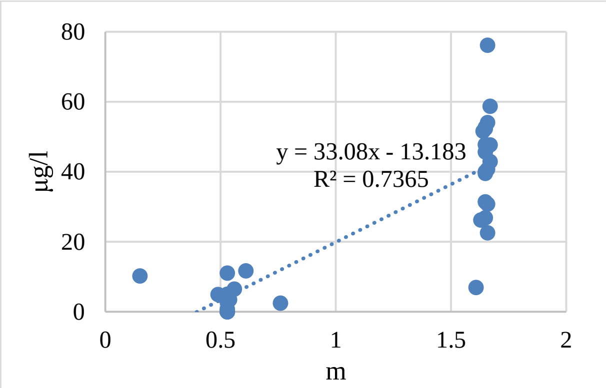

Figure 5 Tasaul Lake - July. Chlorophyll-a concentration in green algae depending on the water depth

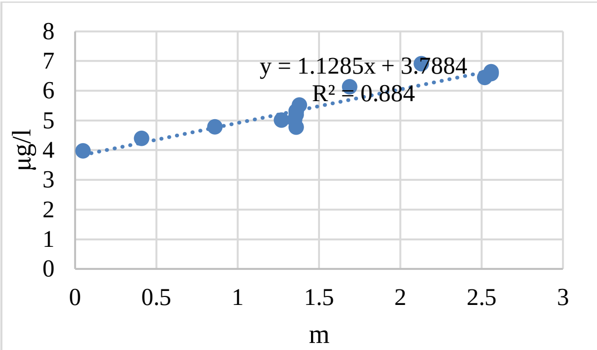

Figure 6 Midia Navodari - July. Chlorophyll-a concentration in green algae depending on the water depth

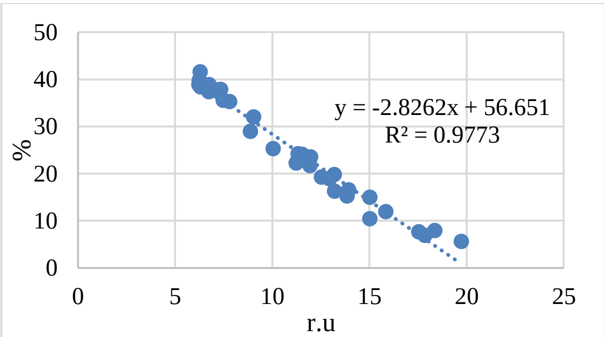

Figure 7 Tasaul Lake - July. The transmittance depending on the yellow substance

The yellow substance originating from detritus and decomposing organic matter has an important role in the transmission of light in the water column, with influence on algal productivity. Except for the April measurements in Siutghiol Lake, for all other measurements a very good correlation was found between the value of the yellow substance and transmittance, $0.95<R^2<0.99$ (fig. 7).

4. CONCLUSIONS

From the point of view of the physical-chemical parameters analyzed, it can be said that, for the time period considered, all the analyzed parameters were within normal limits, with small exceptions in the case of Tasaul Lake (e.g. pH higher than 9). According to the Romanian legislation, the analyzed waters can most often be classified in quality classes 1 and 2, with the exception of Tasaul Lake which, from the point of view of the content of phosphate ions, can be classified in quality class 4.

From the biological parameters point of view, we note the absence of the Cryptophyta group from the analysed water bodies in the Midia Black Sea area and we found it with the greatest abundance in Tasaul Lake. Cryptophytes are often used to feed small zooplankton, which are the food source for small fish in aquaculture.

On the other hand, Diatoms are extremely important components of phytoplankton, the group being one of the biggest contributors to global primary production and being used by specialists to monitor environmental changes over time. Diatoms were constantly found in the Midia Black Sea coastal zone, on the other hand, in the case of lake waters, the group of diatoms was present only in the vernal season. The Cyanophyceae group can proliferate in the presence of excessive nutrients (primarily phosphorus), slow-moving or stagnant water, and heat. In the studied waters, the lakes recorded massive increases in cyanophytes (5 times the case of Siutghiol Lake, respectively 13 times Tasaul Lake). The primary production, as the trophic base in these three water bodies, is strictly linked to the chlorophyll concentration, therefore understanding the mechanisms that influence the variations in algal densities in the three investigated locations will help to make decisions in the application of strategies for the sustainable development of fish stocks. In order to maintain and preserve fish resources, the overall biodiversity of water bodies must be preserved. These involve coherent water quality monitoring strategies and measures for the sustainable exploitation of biological aquatic resources.

5. ACKNOWLEDGMENTS

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PRODUCTION OPTIMIZATION USING PETRI NETS

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Abstract : The work finds purpose in the development of automating fibrous bag palletizing solutions. Using Petri nets, representation and studying of the entire process in a simple manner was possible, from bag apprehension until the final palletization of the filled bags – which allowed the analysis of system performance. Using PIPE, different process configurations were laid out and with FlexSim 2024 a virtual representation of the production line was made.
Key words : bag filling, automation, configurations, palletization, Petri, process.

1. INTRODUCTION

A Petri network is a graph type of mathematical model, used for the virtual analysis of distribution of system elements. It is made out of places and transitions interconnected through arcs which generate or consume a set number of tokens – these represent validation objects of the system conditions or, even the workpiece.[1]

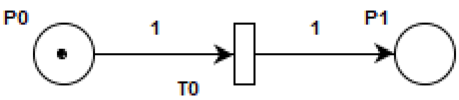

Figure 1 Petri network featuring 2 places and a transition [1]

Above (Figure 1), one can observe, in order, from left to right - an entry place P0 which contains a token, an entry arc with a weight of 1, a transition T0, an exit arc with a weight of 1 and an exit place P1.

Places represent discrete storage spaces for tokens and can serve as entry conditions, necessary storage space or necessary project resources, while a transition is characterized by the use of these tokens and generating them in the next places. Transitions are triggered when every entry place features at least one token – thus they can be representations of an event, a processing stage or a logical condition that must be fulfilled for completion of said stage. These rules of consumption/generation of tokens can be imposed through connection arcs by specifying the arc weight.

We can create logical blocks of place-transition for every process of product processing, thus characterizing the system from a functional point of view in an easy to understand way both by those responsible of process design during production but also by operators during training.[2]

In Figure 2, when we line up processes from the operational production chain that present a linear dependency (the only systems communicating are the ones before and after), we can represent them in a single block of place-transition and during our performance analysis they are represented strictly through their characteristic time parameters.

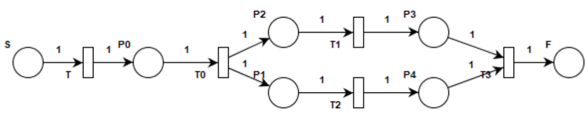

Figure 2 System with processes executed in parallel

When multiple places are connected to the output of a transition, in all the places tokens will be generated. This characteristic allows the representation of operations executed in parallel in an automated system when from a transition in series with a place P0, connected to the source S, are connected two ramifications or more, each with their own process required weight – thus, the branches created become independent of one another and, even though when a Petri net is simulated, they are triggered in a non-deterministic manner, the average of token distribution

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on every place becomes a parameter for system efficiency.[3]

Beyond what was previously mentioned, the concept of coloured Petri networks must be introduced, where tokens can be color-coded so that there can be a multitude of input and output conditions, handled by the arcs that enter and leave the transitions.[4]

.

2. METHOD AND RESEARCH

2.1 The characteristics of manufacturing system:

Everything previously mentioned makes petri networks useful for conceptualization of systems in the field of production, their organization and increase in effectiveness of robots' coordination in various configurations in a short time.

The characteristic parameters of manufacturing systems are characterized by process execution time and the transfer time to the next process which is itself divided into execution time and dead time, respectively the effective transfer time and return time.

- The effective execution time (T) is the time in which, without stopping, the robot or the functional component executes a certain movement in the process.
- The dead time (t) is the waiting time between the moment when a manipulator of the system receives a command and the moment in which it executes it.
- The effective transfer time (T_t) is the time necessary for the transfer of the object destined for processing to the workspace of the next process.
- The return time (T_r) represents the time in which a manipulator travels to its initial position, ready to pick up the next product.

We can observe two aspects regarding the characteristics of the parameters listed above:

I. T and T_r are characteristic only to automated processes, systems containing hardware responsible for control and who account for their surroundings through programming. Thus, a system that is passively functioning can be characterized only through the other two parameters.

II. For the effectiveness of a manipulator to be dependent exclusively on the surrounding systems, its return time must be smaller than the characteristic execution time.

2.2 The structure of model system:

The system proposed for exemplification is made from a needle apprehension device 1 which picks up the empty bags from the source S, which are transported using the conveyor a, coordinated with a manipulator dedicated to the opening and positioning 2 (Figure 3). The bags are picked up by the two pallets of the manipulator, after which they are rotated 90 degrees to vertical position on a scale 3. The apprehension device and the manipulator return to their initial positions while the chute 4 fills the bag with flour, once the desired mass is reached, it continues down the line. In the next stage, the filled bags are moved using the conveyor b to the alignment rails 5, which straightens the edge of the bags and leads them to a tensioning area 6 where they are sealed by the sewing machine 7, so that they can then be palletized in the storage space F.

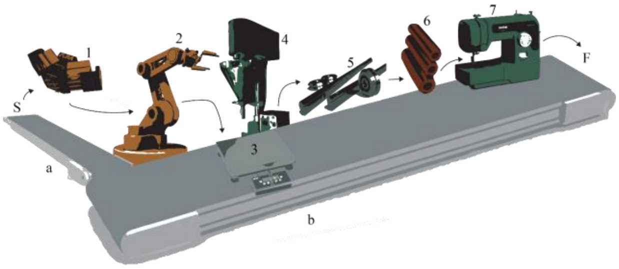

Figure 3 System used for the example
1 – needle apprehension device, 2 – manipulator robot, 3 - scale, 4 – bag filling machine,
5 and 6 – roller based tensioning system with guide rails,
7 – sewing machine.

It must be mentioned that the simulation time is independent of the actual execution time of the processes, but some results following the analysis of the system behaviour offer clues of system effectiveness. Because of this, when we wish to simulate the palletizing of processes, for example with 2 branches, the simulation time can be up to n times bigger. [4]

2.3 Case study:

Below, two studied cases can be observed, both with a number of 100 bags as input:

1. The system with all of the processes necessary for manufacturing being present in the minimum required amount(one type of process – one manufacturing stage, one machine for processing).
2. The system with the processes necessary to manufacturing laid out in parallel (two manufacturing lines in this case), for increasing effectiveness, the distribution and collecting being maintained as common (Figure 4).

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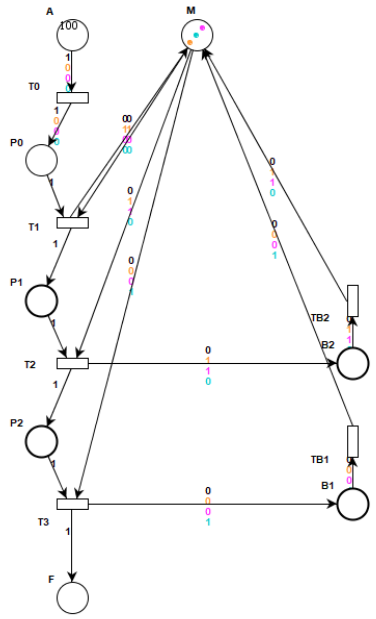
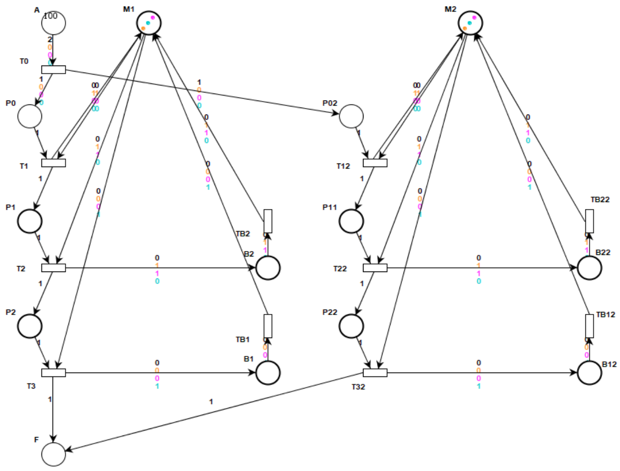


Case I



Case II

. Figure 4 Structure of the studied system

where

A – bag input area; T0 - transport of bags to collecting zone P0 through a conveyor belt; P0 – place designated for the bag pick-up using the needle apprehension device, whose presence is detected using an array of sensors; T1 – transport of the bags to a toppling area P1; P1 – the place in which the apprehension device coordinates with the robotic arm with pallets for opening the bag; T2 – the transportation to the weighing area; P2 – the logical place representative of the weighing, filling, distribution and sewing; T3 – the transitioning towards the palletizing area; F – collector. Palletization takes place here.

3. RESULTS OF SIMULATION

As the results of simulation we can observing following data (Table 1):

Table 1. The simulation results for case I and case II

Place	Average amount of tokens I	Average amount of tokens II
A, supply	16.16805	8.27949
P0	39.76539	21.58984
P02	-	22.46824
Palletized	42.9218	45.30853

Considering the nature of the studied system, the lower number of tokens in case II then in case I represents an increase in effectiveness, characterized through a ratio of places in case II over those of case I.

Based on this information, the production line was simulated using the Autodesk software FlexSim where we considered the same two scenarios as above (Figure 5).

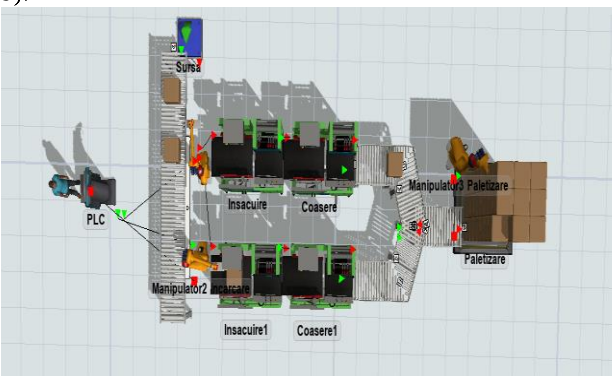


Figure 5 Second simulation

As result of the experiments the following were observed:

- In scenario I on a single branch, despite the generous arrival times of the bags, the lone manipulator is quickly overwhelmed, and the supply conveyor ends up being overcrowded and blocked, one can observe the large medium number of bags on the supply conveyor, the increased functioning time of the loading manipulator and the reduced productivity of the palletizing manipulator (Figure 6).

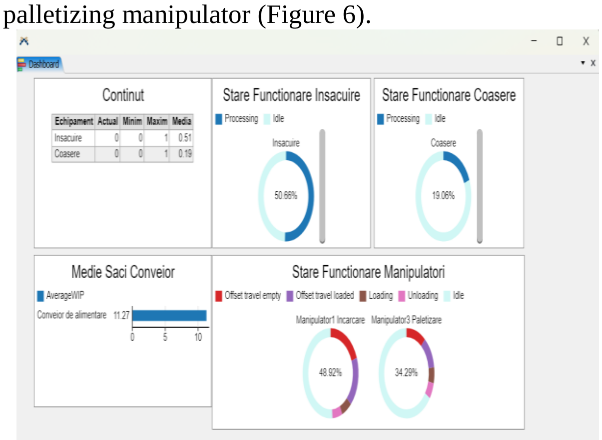


Figure 6 Scenario I, results obtained from single branch processing

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- In scenario II, with two branches, the system handles effectively the number of bags, succeeding in filling and palletizing 100 bags in 17 minutes (Figure 7). The increased efficiency is observed through the reduced medium number of bags on the conveyor and the increased functioning time of the palletizing manipulator which indicates an increase in productivity, meanwhile, the loading manipulators are used less.

Figure 7 Scenario II, the results obtained for two parallel branches

In principle, the single branch processing led to a disproportionate accumulation of bags in a single area of the manufacturing cell in direct correlation with the accumulation of tokens observed in the petri network, the adding of a second branch allowed the fluidization of the process and the prevention of excessive accumulations.[5]

This comparison between one branch and two branches can be easily scaled up to much greater and more complex systems making petri nets useful in production planning, especially when paired with simulation software.[6]

4. CONCLUSIONS

Petri nets are ideal for conceptualizing and easy organizing of factories, being an easy way of graphically interfacing in a logical way the elements responsible for process coordination as well as simple operators. They are also useful in increasing production effectiveness, thus directly increasing profits and motivating choices regarding investments in process automation.

Future research opportunities:

- The generation of formulas based on efficiency factors regarding time for the characterizing of each individual process.
- The conceiving of a specialized program which ensures communication between a live petri net and the robots of a factory.
- Increasing the range of applicability for coloured Petri nets.

5. ACKNOWLEDGMENTS

Thank you for support to publish my article by Constanta Maritime University, Scientifically Session of Students , May 2024.

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PRACTICAL SESSION USED FOR A DEEPER UNDERSTANDING OF VAPOUR COMPRESSION SYSTEMS – A PURPOSE OF TEACHING IN CONSTANTA MARITIME UNIVERSITY

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Abstract: In order to increase the knowledge of future marine engineers it is needed to bring closer the practical skills with theoretical gains. In Constanta Maritime University, Marine Refrigerating Plants is a discipline included in the curricula of future marine engineers. Practical learning can be also developed on low cost and effective means – as it will be proven in the paper. By using Coolselector 2, future marine engineers are trained to apply theoretical knowledge such as thermodynamics principles and to better understand the vapour compression cycle analysis, thermodynamic properties of refrigerants or the importance of the main components of a basic vapour compression refrigeration cycle. At the end of the practical session, students will gain important skills specific to theoretical aspects of refrigeration and thermodynamic processes and real situations.
Key words: vapour compression refrigeration, practical session, theory.

1. INTRODUCTION

Refrigeration systems are developed based on the laws of thermodynamics, refrigeration being a modern technology which is implied in our daily lives.

One of the most used refrigeration system is represented by vapour compression refrigeration system (VCRS) which contains as main elements the compressor, condenser, throttling valve and evaporator.

The refrigerant is the working fluid – it absorbs heat from a space or a product and releases the heat elsewhere [1].

These systems are important for the marine refrigeration sector.

VCRSs are widely used to extract heat from the cold space and to control temperature in order to preserve the quality of perishables during voyage [2], [3].

Also, VCRSs are vital for the thermal comfort of crew and passenger on board [4].

On board the ships, VCRSs are associated with high amounts of energy consumed, shipping companies being aware of the need to exploit these equipment in the most efficient way [5].

In this context, future engineers dealing with refrigeration systems need to enhance their theoretical knowledge by the help of practical sessions, in order to understand how the first and second laws determine the working of these systems and to handle the performance of the specific cycles [6].

On the other hand, traditional teaching is not sufficient any more, digital means of gaining skills being more motivating; with a simple “click” students might be better involved in thinking, learning or exploration a topic [7].

This paper describes a practical session specific to vapour compression refrigeration cycles – a topic important for future marine engineers when aiming gain of theoretical and practical skills.

2. VCRSs THEORETICAL FORMULATION

Refrigeration systems are based on reversed Carnot Cycle, these systems being able to extract heat from a hot sink and reject heat to a cold one, by consuming external work; they rise environmental concern directly and indirectly [8].

The simplest ideal VCR cycle is provided in Figure 1; are given the main processes and the equations used for cycle analysis which are set on mass and energy conservation basis [9], [10].

During the compression, the refrigerant is compressed at constant entropy (isentropic process), while in the condenser takes place an isobaric heat rejection process.

During the expansion, there is an isenthalpic (constant enthalpy) process which brings the pressure of the refrigerant to the evaporator pressure value.

In the evaporator takes place an isobaric heat addition to the refrigerant.

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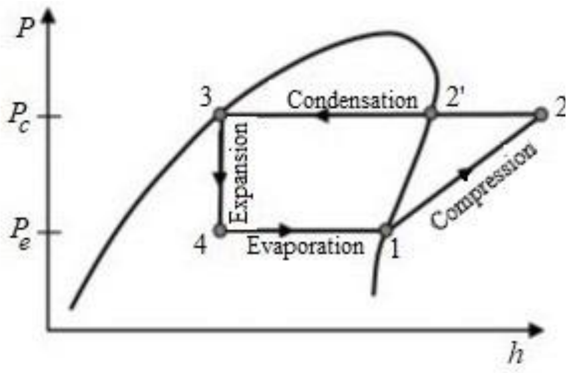

Figure 1 Standard vapour compression refrigeration cycle [9]

The heat absorbed in the evaporator is found as:

$$Q_e = (h_1 - h_4) \quad (1)$$

where:

h – enthalpy, kJ/kg

The compressor input is calculated with:

$$W_{comp} = (h_2 - h_1) \quad (2)$$

The heat evacuated in the condenser is calculated as:

$$Q_c = (h_2 - h_3) \quad (3)$$

While the Coefficient of Performance is obtained with the ratio:

$$COP = \frac{Q_e}{W_{comp}} \quad (4)$$

3. REFRIGERATION TEACHING TO FUTURE MARINE ENGINEERS

Engineers on board the ships have to face specific challenges such as ships' safety, reliability or efficiency, this is why maritime universities must offer educational programme able to serve a sophisticated industry.

In the list of courses included in such programs, Refrigeration and Air Conditioning is found together with Mechanics, Thermodynamics, Marine Power Plants, Environment Protection and so on [11].

In order to enhance engineering thinking and skills, universities pay attention to the use of software and virtual labs for the benefit of their students [12].

In Constanta Maritime University, Marine Refrigeration Plants is included in the Naval Electromechanics – Bachelor of Science, Semester 7.

It is developed on 28 hours of courses and 14 hours of labs.

The course and lab contents are provided below and are in accordance with STCW Codes (7.04.1.4.1.6.2.a; 7.04.1.4.1.6.2.b; 7.04.1.4.1.6.2.c; 7.04.4.1.6.2.d; 7.04.1.4.1.6.2.e; 7.04.1.4.1.6.2.f; 7.04.1.4.1.6.3).

Theoretical knowledge covers: refrigeration cycles, the principles of refrigeration, refrigeration compressor, marine refrigeration components, brine and refrigerants, cooling spaces, air conditioning and ventilation.

Teaching methods specific to the lab activities includes the use of the university's e-platform, tables and diagrams, Coolselector program.

4. A PRACTICE SESSION EXEMPLIFICATION

In order to strengthen the link between theoretical and practical knowledge of students, expansive equipment is not compulsory; low cost and available alternatives replacing real machines show their efficiency when aiming refrigeration learning and practical knowledge acquisition [13].

In Constanta Maritime University, practical sessions respect the above mention by the use of Coolselector 2, developed by Danfoss.

Simple "clicks" provide logp-h diagrams for several refrigerants in order to perform calculations, find efficiency, analyse situations at different operating conditions and so on.

In the following it is described a practical session when using Coolselector 2.

The topic of the session is: ***ANALYSIS OF THE SINGLE STAGE VAPOUR COMPRESSION REFRIGERATION CYCLE USED FOR THE TRANSPORT OF DAIRY PRODUCTS.***

Are provided theoretical aspects and are mentioned the materials required: computer, Coolselector 2 software, p-h diagram for the working refrigerant.

Are defined the objectives of the practical session: the familiarization with specific terminology, visualization of operating conditions, determination of COP, refrigerating power, power consumed by the compressor - for different external temperatures, visualization of the refrigerating cycle, finding out the parameters at the points of the cycle.

It is given the working method as follows:

1. Open Coolselector 2 software
2. Select "Commercial Applications"
3. Select "Cold Rooms"
4. Select "Define Cold Load"
5. Introduce the dimensions of the cooled compartment and select the external parameters of the room: we assume that we are navigating in an area where the outside temperature is 30 ^{0}C.
6. Click on the "Next" button.
7. Select the type of transported product: dairy.
8. Choose the transported quantity: 3t (3000 kg).
9. Dairy products are transported at 5 ^{0}C , so choose this value at "Inlet temperature".
10. Click on "Next" button.

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11. Choose the relative humidity in the cooled space of 80% (from "Relative humidity") and click on "Estimate operating hours".
12. Click on "Select" button.
13. We can visualize the created situation.
14. Click on "Next" button.
15. Select region of transportation from "Select region".
16. Select the aggregate type by clicking on "Optyma Slim Pack" button.
17. We choose the refrigerant from "Select refrigerant".
18. Click " Next" and view some of the necessary equipment.
19. Click " Next" .
20. Visualize the operating conditions.
21. Click "Select".
22. View details such as: COP, cooling capacity, power consumed by the compressor (Power consumption) - at different outside temperatures and at different vaporization temperatures, etc.
23 Click on "Performance details".
24. Click on "Detailed log p-h diagram".
25. Visualize the cycle specific for the plant on board.
26. By positioning the mouse on the points of the cycle, read the thermodynamic parameters at the points of the cycle (T, p, v, etc.).

Students will record the red data. By using log p-h diagram, students will have their own calculation and will confront their results with the one found by using the software.

Figure 2 illustrates the situation created.

The region selected was “Middle East”, and the chosen refrigerant is R134a.

It is generated Figure 3, from which students are able to see the components from the cold room.

Figures 4 and 5 offer information on cooling capacity and power consumption, while the generated cycle is seen in Figure 6.

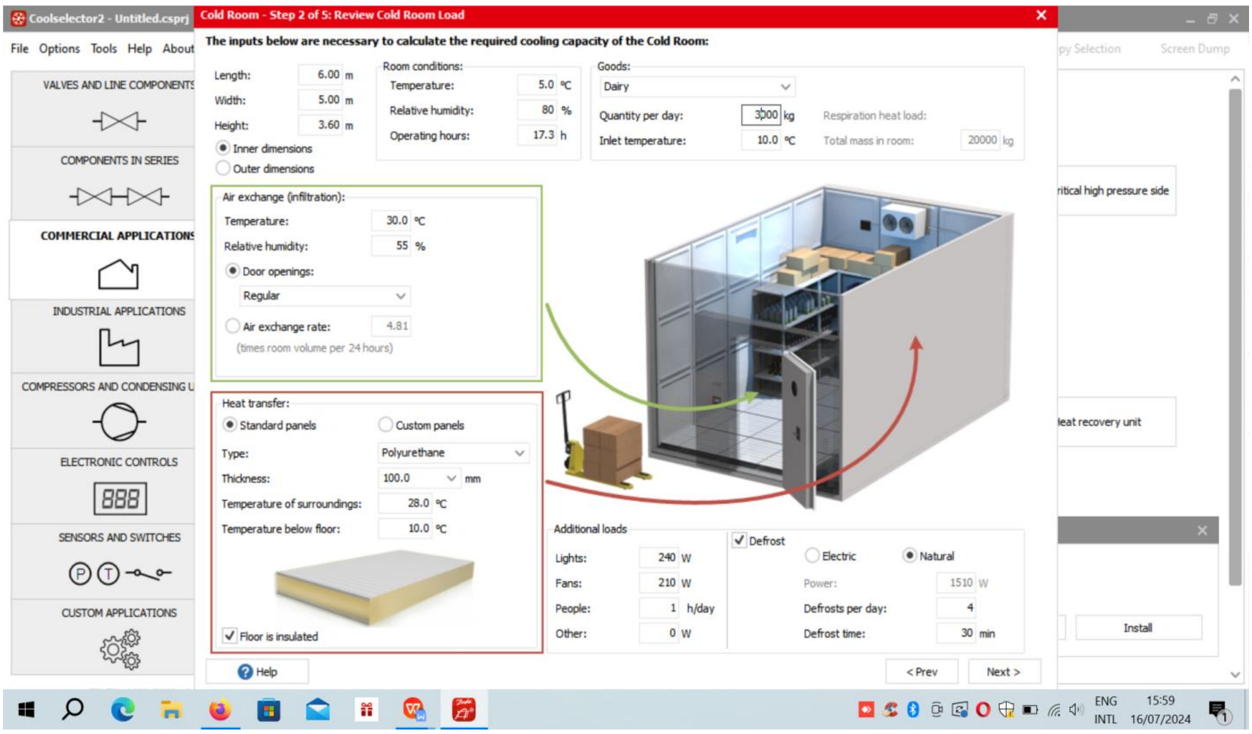

Figure 2 Generated cold room

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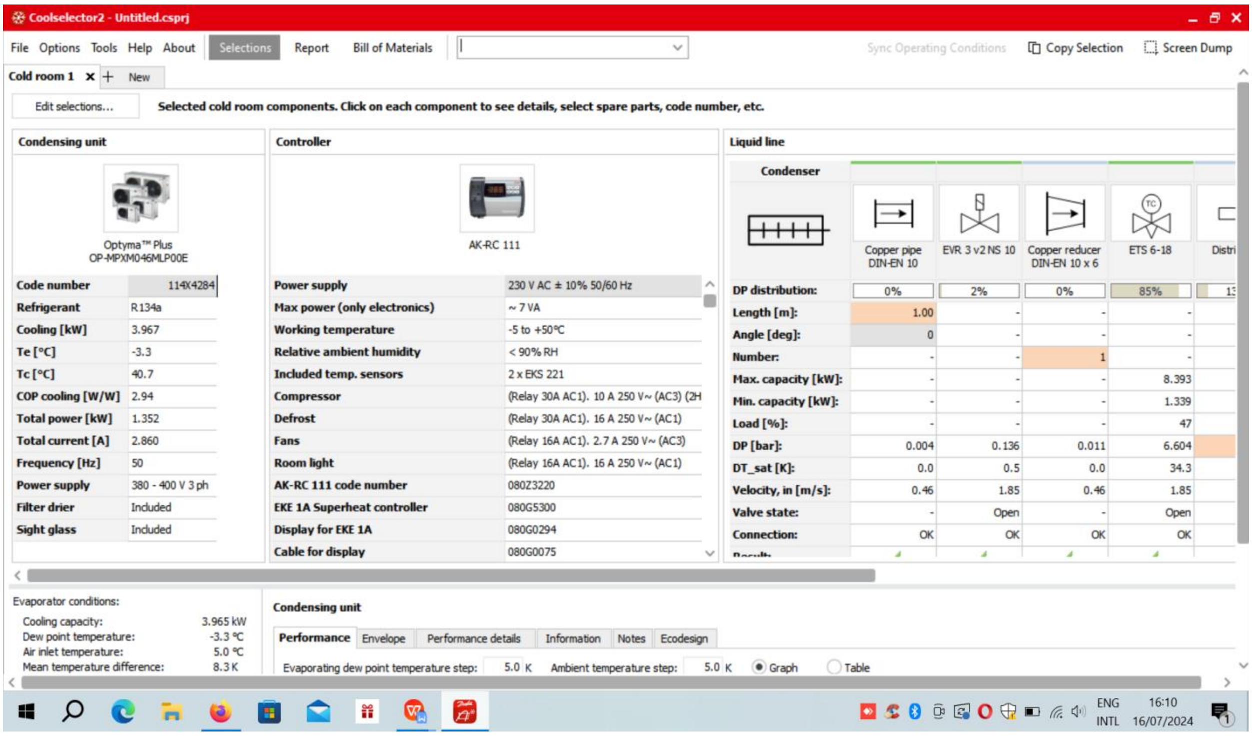

Figure 3 Components from the generated cold room

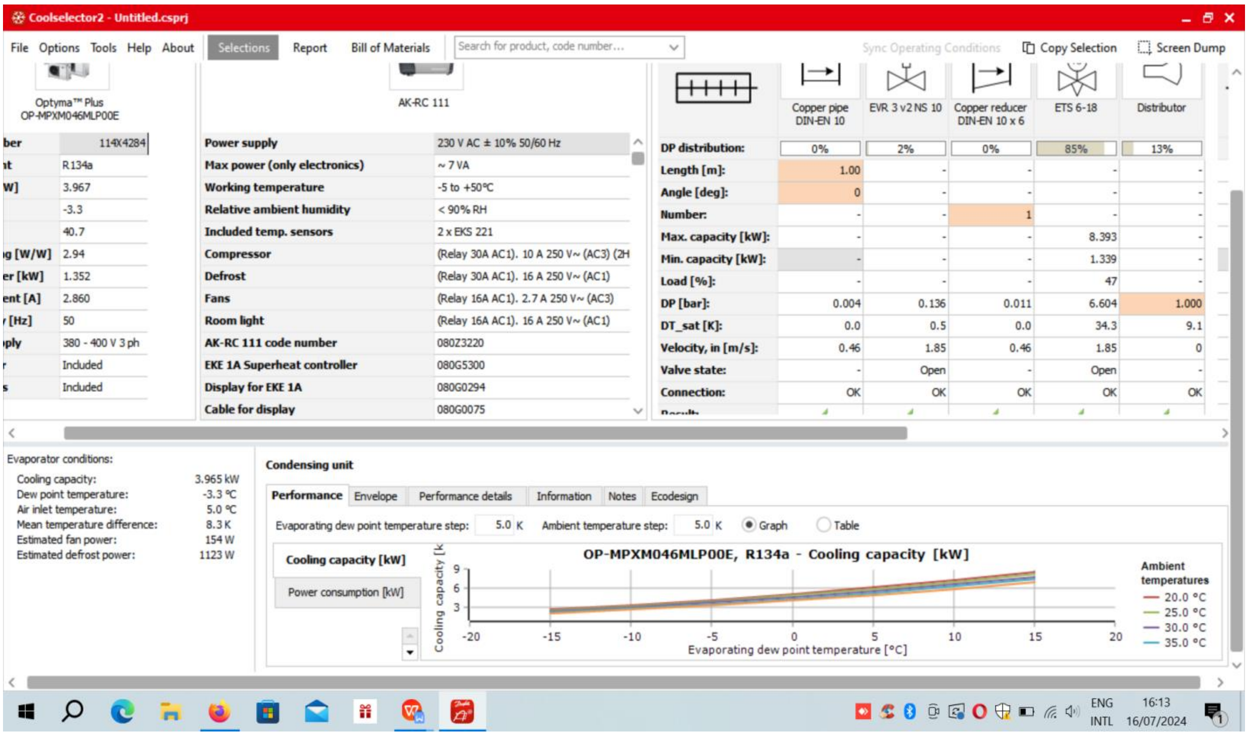

Figure 4 Cooling capacity for different ambient temperatures

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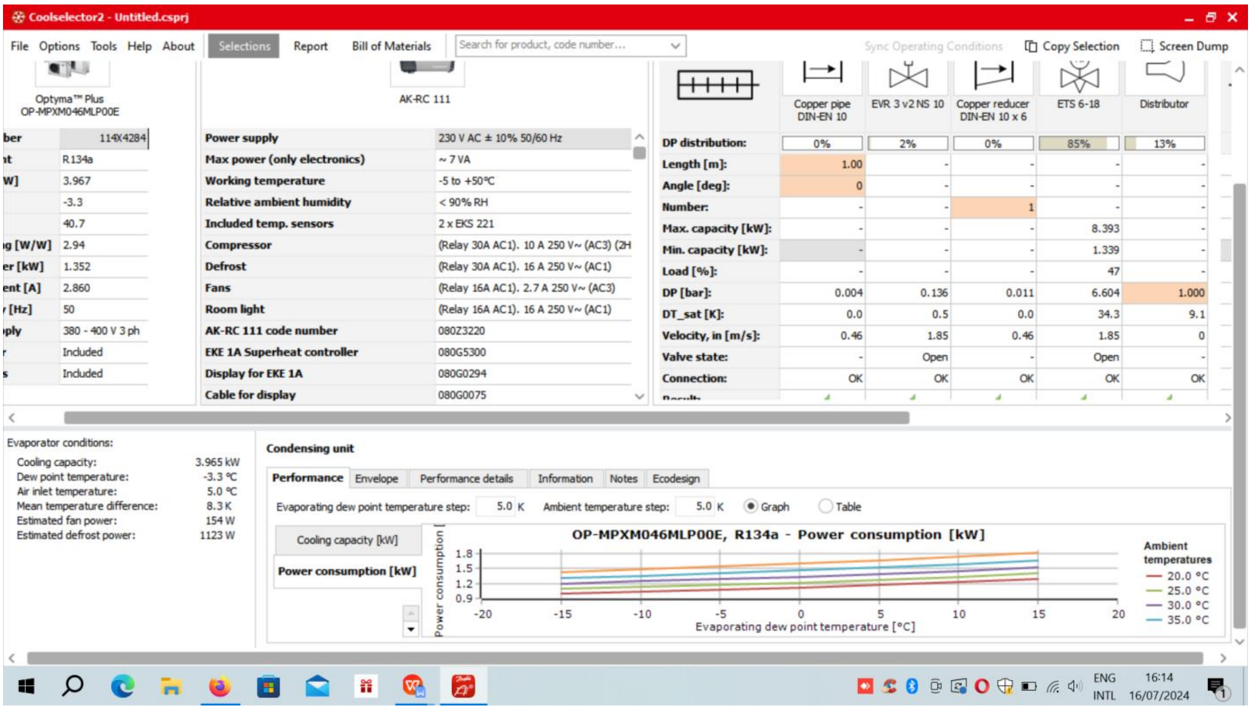

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Figure 5 Power consumption for different ambient temperatures

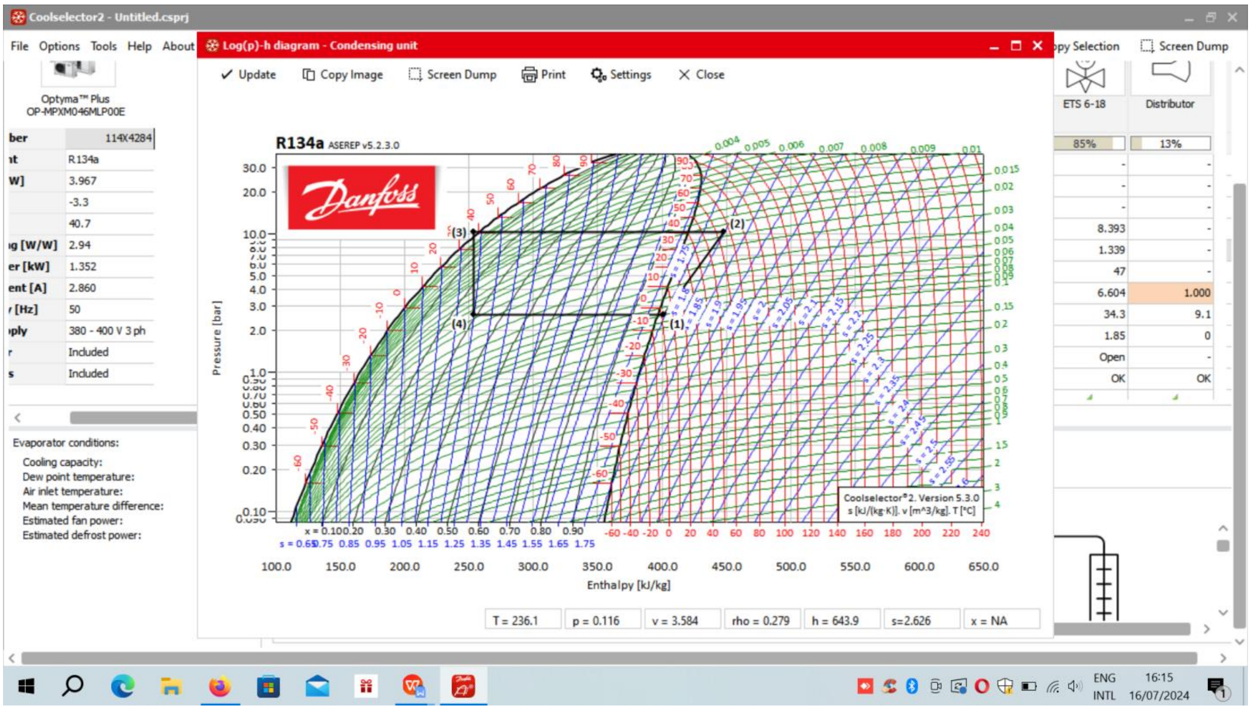

Figure 6 Refrigeration cycle in pressure- enthalpy diagram

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5. CONCLUSIONS

In this paper was described a low cost and efficient manner of developing a practical session specific to the discipline Marine Refrigeration Plants – included in the curricula of future marine engineers trained in Constanta Maritime University.

By using Coolselector 2, students are able to achieve a deeper understanding of vapour compression systems and to connect better theoretical knowledge with practice.

The attractiveness of this teaching methodology consists mostly in the fact that students might create their own situations, by choosing the type of perishable to be transported, the external and internal conditions or the working refrigerant.

The findings obtained by the help of the software can be compared with the results obtain with traditional calculations.

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MAXIMIZING SELF-CONSUMPTION FROM PHOTOVOLTAICS

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Abstract : The present study refers to the maximization of self-consumption through the automation of a residential consumer that is or not fed from the low-voltage electrical network and from its own photovoltaic system. The level of self-consumption from photovoltaic sources in the residential sector is strictly dependent on the power installed in the own sources, as well as the load profile of the respective consumer.
Two major directions are relevant regarding the possibility of increasing and optimizing self-consumption: the management of electrical energy storage systems (especially through the use of battery systems), respectively the implementation of load management systems, through the partial or total redistribution of their operation over time, but also through prioritization of critical consumers
Key words : consumption, electric, energy, hybrid, load, network, production, photovoltaics.

1. INTRODUCTION

The A conventional photovoltaic system, called on-grid, provides electricity for a household mainly during the day. Most of the energy produced by this way is fed into the network because it cannot be consumed without automation, i.e. more than 30% of the electricity. The off-grid hybrid system represents an energy storage system in batteries. This is profitable because self-consumption is doubled to about 60%. Its disadvantage is the price, which is still very high.

The cheap alternative for using photovoltaic electricity, instead of supplying energy to the public grid at a very low price for the prosumer in relation to the price of energy consumed from the grid, is to convert this energy for water heating, home heating, thermal storage in inertial thermal mass (daily or seasonal) or the charging option of an electric car.

For the energy produced in the middle of the day, when it is assumed that the share of energy from photovoltaic sources would be maximum, there should be consumers who absorb all this amount of electricity produced instantly. Situations are reached that have become common through the repetitiveness observed on weekends when, due to the lack of electricity consumption, its sale price has reached 0 or negative values. The minimum instantaneous consumption reached 3250 MW at the national level on 05.06.2024, which is reflected in negative prices for the sale of energy. But for the household consumer, these negative prices are not noticeable.

Thus, under current conditions, the cheapest form of energy that you can store or convert into another energy source is the one that is produced closest to the place of consumption, namely your own photovoltaic system for electricity production, especially because you are not obliged to pay the transport tax on the network, other cogeneration, environmental taxes.

One of the residential consumer load management methods is oriented towards the use and conversion systems of electrical energy into thermal energy, stored in water from the beneficiary's boilers or buffers. In periods characterized by a surplus of energy, it is used for the preparation of domestic hot water, heating or cooling thresholds. The water level in boilers is monitored with the help of temperature and level sensors, which transmit the information to a central control unit. The disadvantage of such use consists in the need to acquire and transmit additional information regarding the temperature, water level, pressure, water flow consumed, as well as the addressability of the method only to a particular category of receivers. The advantage of a such solution is that it can ensure a certain degree of energy independence, but also a new alignment with the new standards imposed for environmental protection related to climate change, generating a heating without greenhouse gas emissions.

There are two main ways of using this excess electricity, depending on the nature of the generation mode of the photovoltaic system. These can be classified into on grid and off grid systems. In the on-grid systems we can also include systems with hybrid inverters that can ensure energy storage in a direct current storage battery to ensure a backup or to be able to provide energy independence for a certain period of time depending on the capacity of the battery and the chosen

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discharge method or that depends on the used consumers. In the off-grid systems, the inverters used for energy conversion and storage are without the constructive possibility of injecting this electricity into the national electricity distribution network. In this category we can also add inverters called hybrid by some companies, but they can only extract energy from the net, being connected to the low-voltage electricity distribution system. They generally operate by needing a connection to a battery, but there are also inverters that can work without batteries.

It is common to have an overproduction of energy that we don't know what to do with and that is sent to the public grid on a regular basis. One solution to avoid wasting this excess is to send it to an electric water heater, heater, pool pump, etc. For example, if we have a photovoltaic production of 2500 W and 1300 W consumed in the house, we still have 1200 W available for a water heater. The diverter provides 1200 W to the water heater and no more than normal, absorbs 2400 W. The diverter acts as a flow control valve. It ensures that zero watts are withdrawn or injected into the public grid.

2. EXPERIMENTAL SETUP

The system is divided into three functions:
- Shelly Em power meter
- processing using an ESP32 microcontroller (Figure 5);
- actuators with a triac and relays to power different loads with optional control, a temperature sensor.

A current and voltage measurement is performed simultaneously at the entrance to the house. A current sensor is used through which the phase wire from the network passes. At the output it gives the same current, but 2000 times less. The ESP32 microcontroller, through its analog / digital converters, provides and calculates the multiplication of the instantaneous digital quantities of voltage and current, UxI, for power measurement. [1]

2.1 Types of variable regulation of excess load:

A single-phase Shelly Em module installed at the main switch makes it possible to obtain information about the energy consumption network in real time. The actuation of the discharge of the load on a resistive consumer will be done with the help of a triac. To regulate the current to be injected into the water heater or a heater, a drive from RobotDyn or Krida Electronics consisting of a Triac and a voltage zero crossing detection system can be use.

An alternative, to regulate the current to be injected, is to use SSR (Solid State Relay) relays on the free GPIO pins of your choice of the ESP32 to control one or more devices depending on the state of consumption or injection of power at the level of the house. There are many models of 10, 25 or 40A SSR relays for the 230V AC side. The triac or relays can be controlled in various ways to draw the available power (Figure 1).

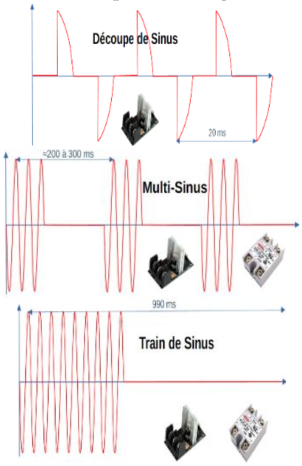
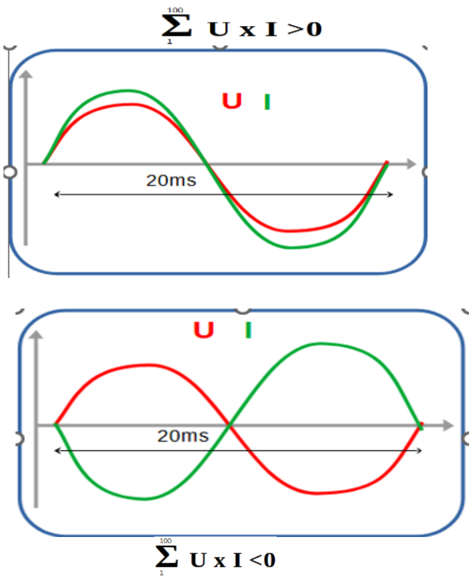


Figure 1 Representation of the 3 types of variable regulation of excess load: dimming, multi-sine, sinusoidal train

They must work in 3.3V voltage level to be able to be controlled via the ESP32 microcontroller.

2.2 The consumption and injection in the network:

At the entrance to the house when the voltage U and the current I are of the same sign, this means consumption. Power is injected into the distribution network when the voltage and current are of opposite signs (Figure 2).



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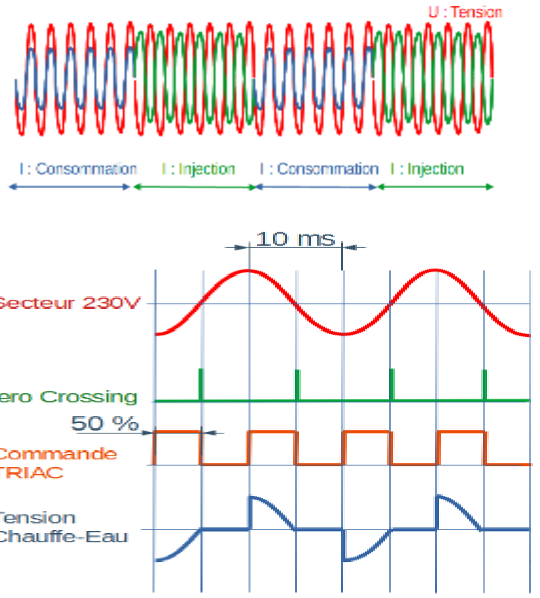
$$P_w = \frac{1}{10000} \sum_{i=1}^{i=10000} U_i \times I_i$$



b)

Figure 2 Representation of U and I in the situation of consumption (a) and injection to the network (b)graphic representation of the waveform - signal crossing through zero - triac command, triac output waveform. [3]

Dimming mode means every 10ms, the Triac is open for a certain duration to adapt to the power to be transferred. Cannot be used for SSR relays. This is useful for water heaters and heaters. It features quick adjustment.

Multi-Sinus means every 200 to 300 ms, we send a burst of several 1/2 sinusoids corresponding to the power to be transferred. This is available for Triac or SSR relays and is useful for water heaters and heaters. It shows slower regulation and less noise generated.

Sinusoidal train menas every 990 ms, the number halfperiods corresponding to the power to be transferred is sent. It is used 990 ms and not 1000 ms to never restart on the same voltage sign and have a continuous component for odd series. This is available for Triac or SSR relays.

At the entrance to the house, the power measurement is done over a time longer than 20 msec to take into account any variation. Measuring equipment used by the distribution operator measures the power over 1s interval. It must have an average of about 10000 UxI products to comprehensively sample the waveform of the voltage U and especially the current I. This average of more than 10000 samples includes consumption periods (currents in phase with voltage) and injection periods (current in phase opposition to voltage). The alternation of consumption and injection takes place in less than one second. They do the arithmetic average and do not count it separately into Wh consumed and Wh injected. It can be observed on the meter, during the periods of regulation by the diverter, the energy we pay or inject correspond to a slower rotation. [1]

In order to know if energy is entering or leaving the house, the electrical voltage must also be measured. It is done by comparing the phase of the current I and the voltage U and by this way we will know the direction of the energy transfer.

In the presence of a dimmer / triac providing a Zc (Zero Crossing Voltage) signal on GPIO23, the operation of the ESP32 is perfectly synchronized with the network. In this way, the moments of opening and closing can be timed with respect to the sinusoid of the mains voltage.[1]

In the absence of a dimmer/triac, it is the internal clock of the ESP32 which provides the synchronization pulse every 10ms. This pulse is asynchronous with respect to the sector. This results in opening and closing of the relays in Multi-Sine or Sinus Train mode not necessarily at zero crossing of the mains voltage. This can cause the relay to heat up more.[2], [3], [4], [5]

3. EXPERIMENTAL RESULTS

In the "Sine Train" mode, when the power cycle is almost one second, the power measurement can be performed according to the measurement time of the second cycle [6]. The control software then needs to average over a long period of time to have a good estimation of the energy consumed / injected exchange and a result similar to the meter of the energy distributor used for billing (Figure 3).

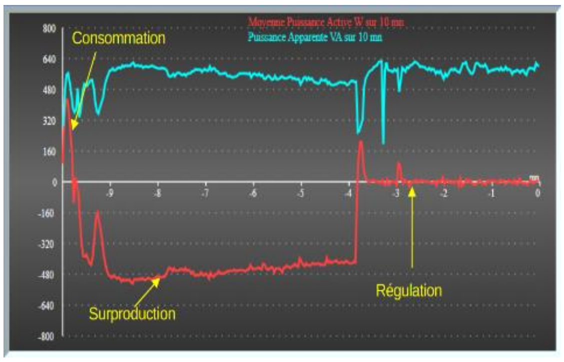


Figure 3 Example of self-consumption regulation, the red curve remains around 0

It can be seen that during the control phases, the apparent power is very high and disturbed. This is normal behavior.

During a 10 ms half sine wave, energy is consumed and injected to have zero active power balance. This results in high apparent power.

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There is, however, a paradox. An apparent power has no sign according to its mathematical definition and is always positive (Figure 4 a,b).

a

Figure 4 a) Active triac dimming with input-output load 2400W

Figure 4 b) Active triac dimming, sun with clouds

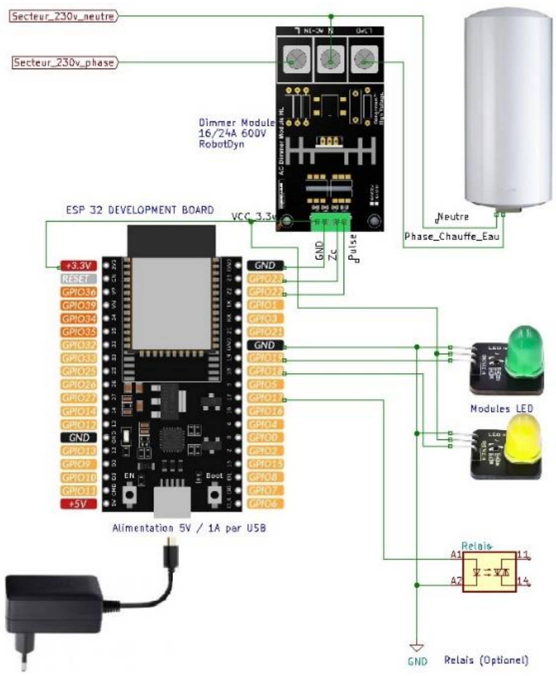

Figure 5 ESP32 control scheme for heating a boiler with water and a consumer connected via SSR relay

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The system for maximizing the electricity produced with an off-grid or hybrid inverter (Figure 6), monitors the battery voltage and the battery discharge current. When the battery is full, then the microcontroller commands the gradual opening of the triac [11], [12].

If the value of the load introduced through the triac exceeds the power available at that moment, the difference between the load discharged through the triac and the additional load will be provided from the energy storage battery.

This fact is monitored by means of a Hall current transducer. When a discharge current over 0.5 A occurs, the microcontroller commands the reduction of the load distributed on the triac until the battery discharge current signal disappears [13].

Figure 6 Off grid system to maximize photovoltaic self-consumption [7]

The software prioritizes critical household consumers and only the available surplus will convert it into another form of energy [8], [9], [10].

4. CONCLUSIONS

The solution to maximize self-consumption, as a form of conversion and storage of electrical energy into another form of energy, from sources considered renewable, is an important step for obtaining a level of energy independence and not only that.

Storing the photovoltaic energy available at times when it is not used directly, in a reservoir with inertial thermal mass, may represent a cheap solution, within reach of those who own a renewable energy source.

Generating space heating with the photovoltaic system is more economical in the long term than operating a gas or oil heating system in the conditions of the continuous increase of their prices.

Basically, every kilowatt-hour that is powered by solar electricity instead of grid electricity counts. This protects the environment and the climate and reduces heating costs.

In this way, important savings can be achieved at household level, but also improve the carbon footprint through self-generated solar energy

6. ACKNOWLEDGMENTS

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ROBOTIC ARM DESIGNED FOR ACTIVITIES IN HAZARDOUS ENVIRONMENTS

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Abstract : The purpose of the project that is presented in this document is to present the idea of a robotic arm that is capable of operating in environments that present imminent damage to living organisms. Mainly , this robotic arm is designed to be easily built, maintained, operated and the possibility to be replaced partially or totally at a reasonable cost and be a reliable tool.
Key words : Arduino, configuration, environment, hardware, hazard, measurement, microcontroller, robot.

1. INTRODUCTION

Robotic arms, aptly named because they resemble a human arm, are typically mounted to a base. The arm contains multiple joints that act as axes that enable a degree of movement. The higher number of rotary joints a robotic arm features, the more freedom of movement it has.

A robotic hand is a mechanical device designed with multiple degrees of freedom to mimic the physiology of the human hand, enabling it to adapt to various constraints and perform tasks such as apprehension and manipulation in coordination with a robotic arm. [1], [2]

2. METHODS AND RESEARCHES

The robot in separated into 2 main parts: the hand and the main console.

The hand is the execution part of the project . It's purpose is to grab objects, move them around, measure the temperature of the object, calculating the distance to obstacles in proximity and avoid them. In order to operate, an Arduino Uno microcontroller is used, which will be referred from now on as "Arduino-HAND". The hand utilizes in its purpose 5 low weight servomotors operating each finger, and one medium weight servomotor operating the wrist.

On the external part of the hand 2 sensors are placed: one thermic and one for proximity. Each sensor is connected to another Arduino Uno microcontroller which will be referred to from now on as "Arduino-LCD". [3]

These controllers are non-linear control elements, which have a static relay characteristic with hysteresis. [4]

The main console is the "head" of the robot, not just for the purpose of controlling the entire ensemble but because of the real-time feedback features as well. The commanding part of the hand are the 2 Arduino microcontrollers mentioned. The feedback part is represented by the LCD located in the middle of the console as well as the module on the top mentioned later on as the "Timer-Module".

The Timer-Module has 2 main purposes, displaying the exact date and time and to overview the temperature at the level of the console. It is important to mention that the temperature detected at the level of the hand and the temperature of the console are entirely different measuring systems, with different purposes and feedback settings.

As presented in the main configuration, although the system is by all means automatic, and can operate without a person giving it commands, it is highly recommended that the robot should be supervised at least in this stage of development.

The external hand presents an addition to the main hand, a piece of material called "The Shield" which has 2 purposes: facilitates the mounting of the sensors and protects the fingers from damage that can intervene due to improperly handling the arm.

2.1 Hardware configuration :

On the shield are placed as shown in the external hand configuration the sensors as follows: the proximity sensor is situated in the upper middle part, identification area extending from the front of the fingers to the backhand and in the bottom center of the shield the temperature sensor is situated, having the purpose of detecting the value of the temperature of the object in

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hand and to prevent thermal degradation I the internal components.

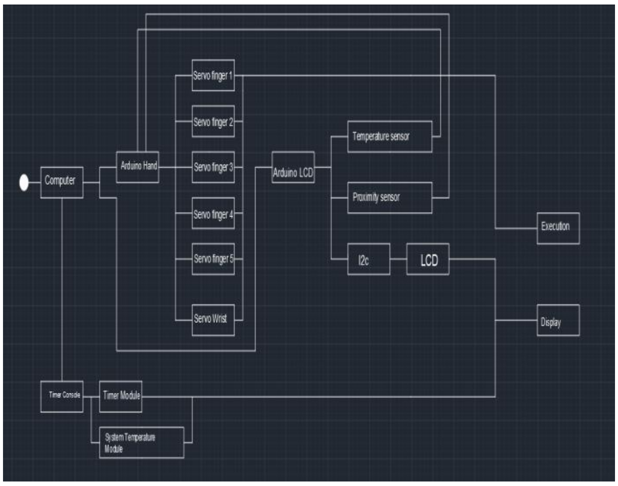

Figure 1 Hardware configuration [5]

Temperature is a physical quantity of great importance for understanding the state of natural and industrial processes. [3]

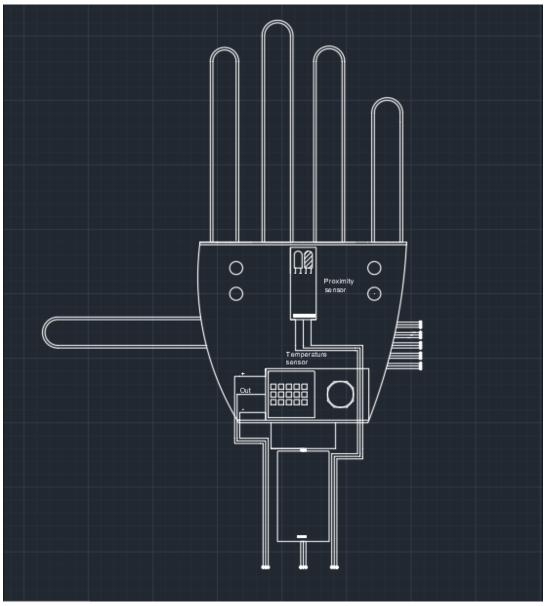

Figure 2 External hand configuration [5]

2.2 The main console of the robot:

The following configuration represents the main console of the robot. This is where the movements are programed, overwritten, the feedback is showns and presents the largest part of the project that can be technologically improved.

The placement of the components is as follows (Figure 3)[5]:

- Top center: Timer Module
- Upper left side : Transformer for Timer-Module
- Center left side : Backup Relays
- Cenrter: LCD
- Upper center: I2C Module
- Center right side: Power supply (reserve)
- Far right side: Timer-Console (small console used to manually program the Timer-Module in case it not displaying the right data)
- Bottom left side: „Arduino_HAND” microcontroller

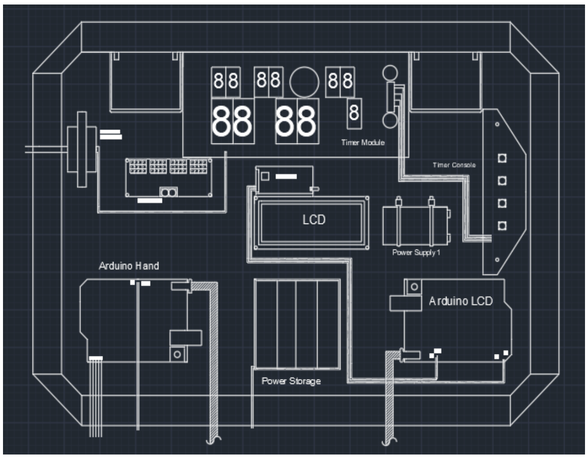

Figure 3 Console configuration

- Bottom side : Power Storage (Inactive at the moment , part of future developmets)
- Bottom right side: „Arduino-LCD” microcontroller.

2.3 The robot's performance:

Control of a multi-fingered robotic hand is usually based on the theoretical analysis of the kinematics and kinetics of the fingers and of the object. However, application of such analyses to a robotic hand is difficult because of modelling errors and uncertainties in the real world. Moreover, the complexity of multi-finger manipulation makes the programming difficult, even for a simple motion.[2]

Paper's:

Speeter [7] described a hardware and software hierarchy to control manipulation with the Utah/MIT dexterous hand, and addressed an abstraction of dexterous manipulation and a control scheme for the Utah/MIT dexterous hand with a set of just over 50 primitives. " A functional approach to the control of manipulation is described and the functional philosophy is embedded within HPL (Hand Programming Language), which provides an abstraction of the process of manipulation through its use of motor primitives".[7]

Michelman [8], [9], [10], [11] showed how the primitive manipulations can be combined into complex tasks.

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Shirai, Kaneko and Tsuji [12] found that the grasp patterns should also be changed according to the surface friction and the geometry of a cross-section of an object in addition to the scale.

Figure 4 Hand representation [5]

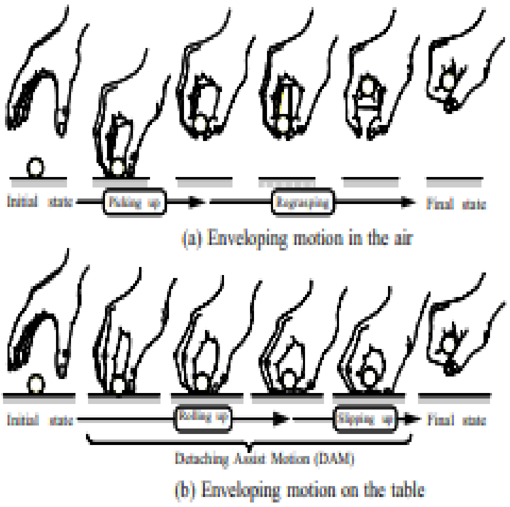

Figure 5 Two Grasp strategies for enveloping an object placed on the table [12]

They verified the grasp strategies by experiments with DAM (Detaching Assist Motion) (Figure 4, Figure 5).[12], [13].

Many other experiments were during the time for robotic arms. [14], [15]

3. CONCLUSIONS

The robotic hand is a tool built with mainly recycled components which is a reliable marker to confirm that it is a cost-friendly pilot project, and it is expected that future development such as adding more types of sensors, adding one more arm or the ability to offer feedback in other ways can only sustain the idea that is presented in this document.

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