National and Technical University of Athens

School of Naval Architecture and Marine Engineering

Division of Marine Engineering

DIPLOMA THESIS:

Development of a web application in computational environment for the NTUA marine-electrical lab web page including applications for the techno-economic feasibility analysis of shore-to-ship connection (Cold - Ironing) and Diesel - Electric retrofit (Battery Ships)

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Abstract

Today's technology development dictates an eagerly growing need of tools available to everyone that needs them. Online provision of these kind of tools promotes fast and easy access as well as large distribution of information and knowledge to the world. The internet has been beneficial regarding this need and a common tool in providing this kind of access. In the meanwhile, concerning naval architecture, various environmental and financial reasons have led to the research of new ways of providing electricity and propulsion to ships. In this thesis, both Shore-to-Ship provision of electricity (Cold-Ironing) and propulsion through batteries in ships instead of Diesel Engines are being included as ways of more economic and environmentally-friendly ways of power distribution to ships. Lastly, every technological institute besides the need for digital online laboratories, also maintain a highly required physical lab. The Institute, the lab and all of the personnel including professors and students could benefit from their own online web page which will provide interested individuals with access to the huge work that is being attained in such laboratories.

Marine-Electrical, the content and subject of this dissertation is an online web application capable of providing such tools and fulfilling some of these requirements. It is built in order to provide all the information about the electrical lab ran by Professor J. M. Prousalidis head of the SNAME Marine Engineering department in the National and Technical University of Athens. It provides the user with an interfaced web page with an easy navigation pattern to all the information needed regarding the lab and the professor, whilst implementing a special tab concerning a digital lab where applications of techno-economical analysis of marine engineering innovations and retrofits are being hosted. As part of this dissertation, the applications implemented consist of one for the analysis of Cold-Ironing in ports and one for the analysis of Diesel-Electric Retrofits in ships. It is designed in a way to provide personalized experience, through an authentication system requiring the user to register for an account that will hold his own projects only available to him and with the ability to highly customize all of the aspects of the project.

In the following chapters all of the methods used for the development, the user interface, the usage information as well as the scientific facts, methods and structure of the application logic are being demonstrated, providing a tool for further development, plus a basic version of a user manual for the whole web app.

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1. Introduction

1.1 Background of the study

The main purpose of this dissertation has been to develop and produce a universal tool accessible to everyone, implementing a cold-ironing analysis application and a diesel-electric retrofit analysis application. One of the main aspects taken into consideration in the development of these tools has been the accessibility that would be provided to anyone with any kind of computational system whether that would be a personal computer running Microsoft's Windows, Mac OS, Linux or even a simple smartphone with access to the internet. In this respect it was vital to build the application as a platform accessible via the internet thus making a web app opened in a typical web browser a perfect choice for this project. As abovementioned such a tool would give the opportunity to students with almost no resources to access a platform capable of giving them major information and results in potential projects as well as project managers to build a basic analysis on potential real-life projects.

As mentioned in other dissertations that have been referenced as very important injections in the current diploma thesis, the development of methods to distribute energy in ships is of great importance. The environment is currently struggling and the human community is struggling even more in order to keep the levels of pollution as low as possible. The matter affects between others, human health, global warming, fauna and flaura decline and quality of life. Maritime transport is currently one of the major factors concerning environmental pollution. On one hand, it is the most environmentally friendly means of transport but on the other hand marine traffic is increasing in large amounts making the pollution caused by it a nonetheless real issue today.

It is clear that a top reason leading to pollution is the production and distribution of energy. Currently most ships produce energy by means of heavy diesel fuel oil for both propulsion and electricity production. Modern systems in comparison to traditional systems of propulsion and electricity production can reduce the emissions by up to 60-70%.

At the same time, the benefits of such technologies expand to financial as well. Cold–Ironing and Diesel-Electric Retrofits can hugely contribute to the reduction of operational costs of ships in port and seagoing conditions respectively. Reducing such costs is vital, however such projects are costly and a techno-economic analysis is mandatory in order to provide us with the required information for a more accurate and correct decision-making. One of the main functions implemented in the application is exactly a tool for this analysis.

A second important purpose of this thesis is the development of an informational web page concerning the details of the electrical laboratory of SNAME and of Mr. J. M. Prousalidis. Telecommunications and especially the internet provide ultra-fast information distributed to anyone with access to it. It would be a mistake for any modern institute not to take advantage of such a powerful tool to expand its horizons and make the research and work a two-way road. In this manner, this second target of this thesis is defined. The power of a web browser and an internet server nowadays has skyrocketed giving us the opportunity to merge both targets (informational & analysis applications) of this thesis in a single multi-purpose web application.

In order to accomplish all these tasks a computational programming background has been mandatory, with some experience in previously ran projects including development of applications either with a User Interface or in a Command Line and knowledge of various programming languages to which the next chapters will be referred.

1.2 Structure of the study

The first steps of the current study were in regard to the research of the technology available concerning Diesel-Electric Retrofits of ships and Shore-to-Ship electricity distribution in ports. These steps are presented in detail in chapters 2 and 3 respectively. In the collection of all the appropriate information, previous studies mainly supervised by professor J. M. Prousalidis, have been of important contribution. Specifically, regarding the Cold-Ironing technology, two studies have been taken into account, one of Mr. Diavatis Ioannis and the second by Mr. Pantazopoulos Dionysios. Concerning the Diesel-Electric Retrofit the studies of both Mr. Bakirtzoglou Christos and Mr. Michail Dimitrios have been the basis of this dissertation. Following these case studies all of the required information and research was collected and put together.

From there on, a research was done on the best possible way to build the kind of application that was required whilst following all the restrictions, objectives and targets that were set. Meanwhile, the structure, functionality and features of previous applications built by Mr. Michail Dimitrios and Mr. Diavatis Ioannis in their own dissertations were taken into account for the sake of multisided perspective and adequacy of the application. Concurrently a research was done on every helpful information on the tools that were going to be used in the building of the app. This whole process is analyzed in chapter 4.

The third step consisted of building the applications themselves running in a web browser. This step took the longest time of all steps due to the big number of tasks that needed to be done, the details that needed to be taken care of and the complexity of computational development itself. In the making of the applications a primary design of the web page that was being created was built. That way in the next step there would not be any need of rebuilding, or redesigning anything.

When both applications were up and running the only thing that was left was to collect all the information regarding the physical lab and Mr. Prousalidis in order to add it in the web page – application. Having done all the appropriate work for the design, simply adding the information in a way that will be explained in chapter 6 was enough.

In the final stages of this project the deployment of the whole application into a live server was needed. A first deployment was done in order to check that everything would work. After that, a small debugging period took place during which the site remained unavailable. With limited access, some tests were run for debugging various design or functional bugs. This does not mean that an application is ever free of bugs, but it can work with a low probability of facing a bug that has not been addressed. The deployment process is being explained in chapter 7. The debugging is not a procedure that can be presented easily however some main bugs that were encountered will be presented.

2. Diesel-Electric Retrofit

As previously mentioned, the methodology and information on the Diesel-Electric Retrofit used was heavily based on Mr. Bakirtzoglou and Mr. Michails' dissertations. Therefore, a detailed summary of those methodologies and information are to be explained here.

2.1 General Information

Diesel-Electric Retrofits in essence refer to a vessel retrofit at which the Main Engines (M/E) and Diesel Generators (D/G, D/E) are replaced with Batteries as a source of power for both propulsion and hotel electricity needs. There are retrofits that refer to simply replacing M/Es with D/Gs through which the electricity generated provides power to a special propulsion system but in this study that is not the case. This retrofit provides benefits to both environment and finance.

Concerning alternative power sources, mankind has been researching and trying to evolve for centuries. One of the major discoveries relating to our study was that of the battery dating back to 1800 by Allessandro Volta. Following a number of other discoveries, in 1834, Jacobi Moritz invented the first ever electric motor to propel a boat. From that day a lot of applications of electric motors have seen the light of day in boats with various innovations some of which were destined to contribute in today's progress of electric propulsion. Lately all studies concerning this kind of alternative power source have been intensified, especially in the 21st century when in 2015 the first all-electric passenger ship was built and put into operation.

Figure 1: MV Ampere - First all-electric ferry (2015) (1)

The MV Ampere was built in Norway under the DNV-GL certification and was designed especially for that purpose.

MV Ampere	
L (m)	80
B (m)	21
Gross Tonnage (t)	1598
Installed Power (kW)	800
Speed (knots)	10
Passengers	360
Cars	120

Today increasingly more shipbuilders, and shipowners, suggest or contribute in the development of electric ships. However, batteries are still in a stage that cannot offer such a large amount of stored power in order to facilitate large vessels in large trips. In this manner retrofits concerning liners of relatively small trips are of huge interest as they can offer interesting benefits. Meanwhile technology is evolving and helping in the development of even larger batteries that will perform in adequacy for all types of ships.

2.2 Technology of Batteries and Vessels

As mentioned, batteries have been in use for the last century in a very large variety of fields. They are categorized in numerous different categories based on their shape, capacity and type.

The maritime-focused systems have mainly been based on Li-ion cells with NMC (Nickel Manganese Cobalt Oxide) cathodes and graphite anodes. Systems based on iron-phosphate cathodes have also been used. Both the NMC and iron-phosphate chemistries represent a good compromise between the most important parameters of safety, energy, power density, life cycle and cost.

A battery system consists of many components and is a highly complex system. For this dissertation a full explanation is not deemed necessary, hence the main components will only be referenced which are:
- Battery cells
- Battery modules arranging hardware
- Battery pack and subpacks
- Thermal management components
- Safety features as fuses, contactors etc.
- Bus-bars and high voltage cabling

- Electronics
- Voltage and temperature sensors
- Low voltage cabling and connectors

In order for the reader to be in position to understand this methodology some of the above components need to be explained. (2)

- A **cell** is the smallest electro chemical unit. An assembly of cells including some level of electronic control forms the **module**.
- The **modules** are connected into series and parallel to form a **sub-pack**. Sub-Pack is the smallest unit that can be electrically isolated. Depending on the system architecture, each sub-pack can have internal relays/contactors which can interrupt main power connection.
- A **battery pack** consists of several parallel **sub-packs**. The battery system may consist of several battery packs. The electrical connections between the different aggregate levels of the battery system may be connected using cables, bus bars or a combination of these.
- The **battery system** consists of one or more **battery packs** including all required systems that can work for the intended purpose as a standalone unit. (2)

The whole battery system is a delicate and sensitive system that needs to be thoroughly placed in a vessel in order to avoid any damage or misbehavior.

Although there are plenty alternatives for the design of the propulsion system, for the better understanding of the conversion an example for a specific vessel will be presented.

The vessel is a Roll-on Roll-off Passenger double ended vessel. It is equipped with 4 main engines, 4 azipod thrusters. The battery system is divided in 4 different arrays for redundancy and it includes an A/C distribution system.
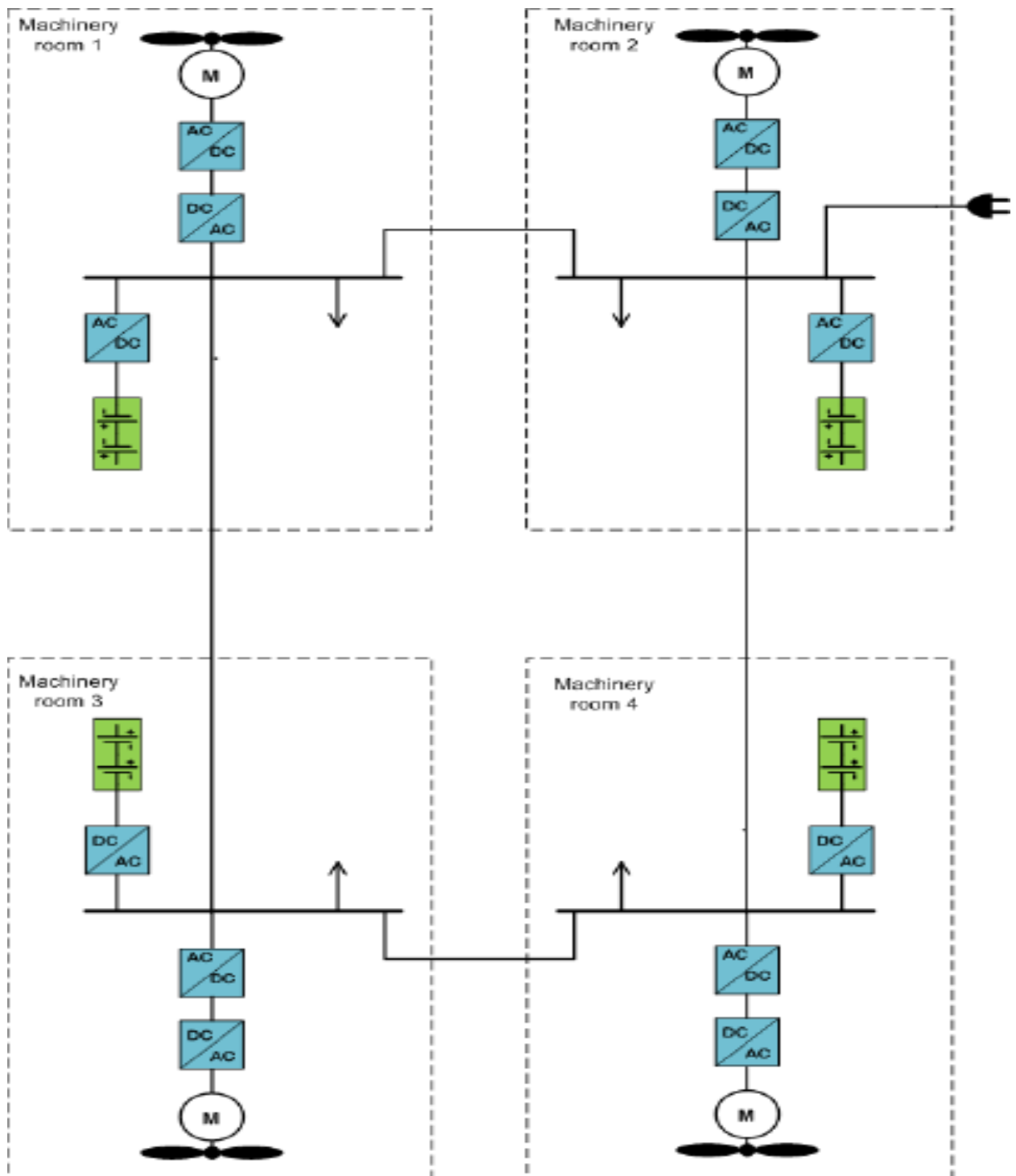
Figure 2: All-electric ship with AC distribution network (2)

The main components of this configuration are:
- Four inverters (AC/ DC), one after every battery array, for the conversion of the DC voltage of the batteries to AC.
- Four back-to-back converters (AC/DC/AC) for the control of the induction propulsion motors of nominal power equal or greater to the nominal power of the motor.
- 4 three-phase AC cables for the interconnection of the machinery rooms.

Similarly, a configuration concerning the shore – side system that will feed and recharge ship batteries is needed. However, it is none of our concern in the current dissertation so there will be no more reference to it.

2.3 Retrofit Analysis Calculation

The purpose of the analysis has been to provide the user with enough information as to if a retrofit on an already operating vessel would be viable and profitable. The main methodology used for this analysis consists of 4 pieces.

First and foremost, a ship with all of its specifications and details has to be registered. Specifically:
- No. of M/Es
- M/E MCR
- M/E NCR
- M/E Manoeuvring Load
- M/E NCR Consumption
- M/E Manoeuvring Consumption
- M/E Efficiency Factor
- No. of G/Es
- G/E MCR
- G/E NCR
- G/E Manoeuvring Load
- G/E Port Load
- G/E NCR Consumption
- G/E Manoeuvring Consumption
- G/E Port Consumption
- G/E Efficiency Factor
- System's DC Voltage (V)

Secondly, a registry of a battery including all of the information concerning it is needed. The data necessary consists of:

- V Nominal (V)
- Capacity (Ah)
- Price ($/kW)
- Dimensions (m)
- Charging Current (A)
- Charging Current for Max Lifespan (h)
- Charging Time per cycle for Max Lifespan (A)
- Lifespan (years)
- Depth of Discharge

Third, the trip information regarding the ship that is being analyzed is mandatory in order to provide a detailed report:

- Days of Operation
- Trips / Day
- Port Time
- Seagoing Time
- Manoeuvring Time
- Diversity Factor

Last but not least, all of the financial data and indicators have to be provided for the report to be accurate at the time of calculation, together with the personalized aspects of the project that one could require:

1. Operation and Maintenance
   a. Electricity cost ($/kW) in port
   b. Fuel cost ($/Ton)
   c. M/E Maintenance Cost per year
   d. M/E Shaft Maintenance Cost per year
   e. G/E Maintenance Cost per year
   f. Battery Maintenance Cost per year
2. Buy & Sell Prices
   a. Initial Discount
   b. Grant
   c. Inverter Price
   d. Motordriver Price
   e. Electric Motor Price

      f. M/E Sale Price

      g. G/E Sale Price

3. Longterm indicators & Loan
    a. Years to calculate
    b. Electricity and Fuel Growing Rates
    c. Loan Value
    d. Loan Interest
    e. Loan Payout Time

Of course, some of these values can be ignored should one choose not to include the corresponding aspects in their research (e.g. no loan or no grant).

Once all the data is in place a series of calculation takes place in order to produce the pleasing result.

The longterm goal is to find the total cost of the batteries needed and provided the sale prices, grants, discounts and loans to proceed to a financial analysis of how the project will be amortized and whether it is a beneficial investment.

In order to do that the first step of the procedure consists of calculating the required energy of the vessel to complete a single trip which will lead eventually by simple calculations to the energy needed per day.

Here two different methods of calculation can be implemented:

1. The first method is with intermediate charging. This means that the vessel after each trip or voyage will have the chance to charge and will charge some amount of power into the batteries. This method gives the ship the opportunity to travel longer before a full discharge takes place and time to charge is needed for the next trip to start. In this case the time needed to plug in/off the vessel from the shore grid's charger is required as a piece of data for the calculations.

2. The other method is with the number of trips needed to be done between two full charging sessions. In this case, the ship travels without plugging in/off in the port but at some point drains out of battery hence needs to be charged full again in order to operate a new cycle of trips without charging. If this kind of calculation is preferred the number of trips without charging has to be provided as data.

Knowing the energy needed to be installed on the vessel in either situation the number of battery modules can be calculated and thus the number batteries needed in total. That produces a weight number of the batteries and finally a cost of the batteries.

Now that the installation cost of the batteries is known, the costs of fuel, operation and maintenance of M/Es and G/Es are calculated alongside the same costs when using batteries. The two lists of costs are compared and an annual benefit is calculated given that the costs in general with battery usage are always lower than those of traditional propulsion

systems. At the same time the sales prices are also subtracted from the initial cost of the batteries and with the multiplication of the annual benefit in years a total benefit over the years is calculated. At this point a loan or a grant is also taken into consideration alongside the growing rates of fuel and electricity, thus affecting the worth of the investment.

3. Shore-to-Ship Power distribution (Cold-Ironing)

3.1 General Information

This part of the study, similarly to the previous one, was done with the help of two other dissertations. Those of Mr. Diavatis and Mr. Pantazopoulos.

Cold – Ironing is a technology that mainly refers to the distribution of electricity from shore (Ground Power Station) to ship to counterbalance the use of Diesel Generators on the vessel at port. Hence the ship could have all of its engines off at port which results in zero fuel consumption and of course zero emissions.

Equivalent to the Diesel-Electric Retrofit the interest for Cold-Ironing depends very much on the same reasons due to its very similar benefits and reasons of application. The nature of the innovation and especially the time and place that Cold-Ironing takes place, which is at port, in long-term intervals of ship cruising, makes it arguably an even more interesting technology especially to the citizens living close to the ports. Many ports nowadays suffer from increased fuel emissions resulting in the whole city behind them suffering from extremely poor quality of air.

The resolution to this problem might be found in the deployment of the Cold-Ironing technology. Increasingly more vessels are starting to use this innovation not only to reduce their emissions (which in some cases is required by the policy of the port or the state) but to reduce the load of their Diesel Generators at port. An advantage of great importance when it comes to large cruisers or containerships staying at dock for 2-3 days or more.

MARPOL also pushes in the same direction with the latest years being increasingly strict while sulfur limits both at sea areas and ECAs (Emission Control Areas) drop, with the latest news being the new limit active from 1st January 2020, 0.5% m/m at sea and 0.1% m/m at ECAs.

Area	Sulphur limit	Scrubbers
Global	0.50% (2020)	Local restrictions may apply for open-loop scrubbers
SECA	0.10%	Yes
EU	0.10% in all ports	Open-loop scrubbers restricted in some countries
China	0.50% in national waters (12 nm)	Certain restrictions apply for open-loop scrubbers
California	0.10% within 24 nm	No, only with research exemption

☐ 0.50% limit, global (MARPOL, 2020)
■ 0.10% limit, SECAs (MARPOL)
■ 0.50% limit, China national waters (12 nm), 2019

Figure 3: Latest Sulphur Limits of Ships (2020) (3)

Already some ports of the world support Cold-Ironing, however fulfilling all of the requirements that may be present by the variety of ships is not an easy task. Regarding electrical current and frequency of AC, vessels propose a wide variety, thus making the compatibility between them and a cold-ironing installment an acknowledged issue. For this issue to be resolved, Frequency Converters and Voltage Transformers have made their way. This way compatibility issues may be almost extinguished.

There is an International Standard published in 2012 called International Standard (ISO/IEC/IEEE 80005-1) which proposes the fundamentals of a Cold-Ironing installation. Following this standard the EU Commission has built a recommended configuration with great advantages. Not all configurations follow this recommendation however the international standard has to be followed. On the other hand the European recommendation has two major disadvantages, leading us to consult another approach, created by Mr. Patrick Ericsson and Ismir Fazlagić in their Master of Science Thesis in Chalmers University of Technology. The proposed configuration has a more centralized scope in which firstly the main port's substation is connected with the national grid. There, one or more parallel connected frequency converters take place. Input and output transformers are connected with each frequency converter to adjust the input and output voltage. A dual frequency option is given by double busbar integration. One busbar is connected with the frequency converters' output current while the second one is connected via a voltage transformer to the national grid. A circuit breaker and a change-over switch are used to transmit power to the berth-side in whichever frequency needed. (2)
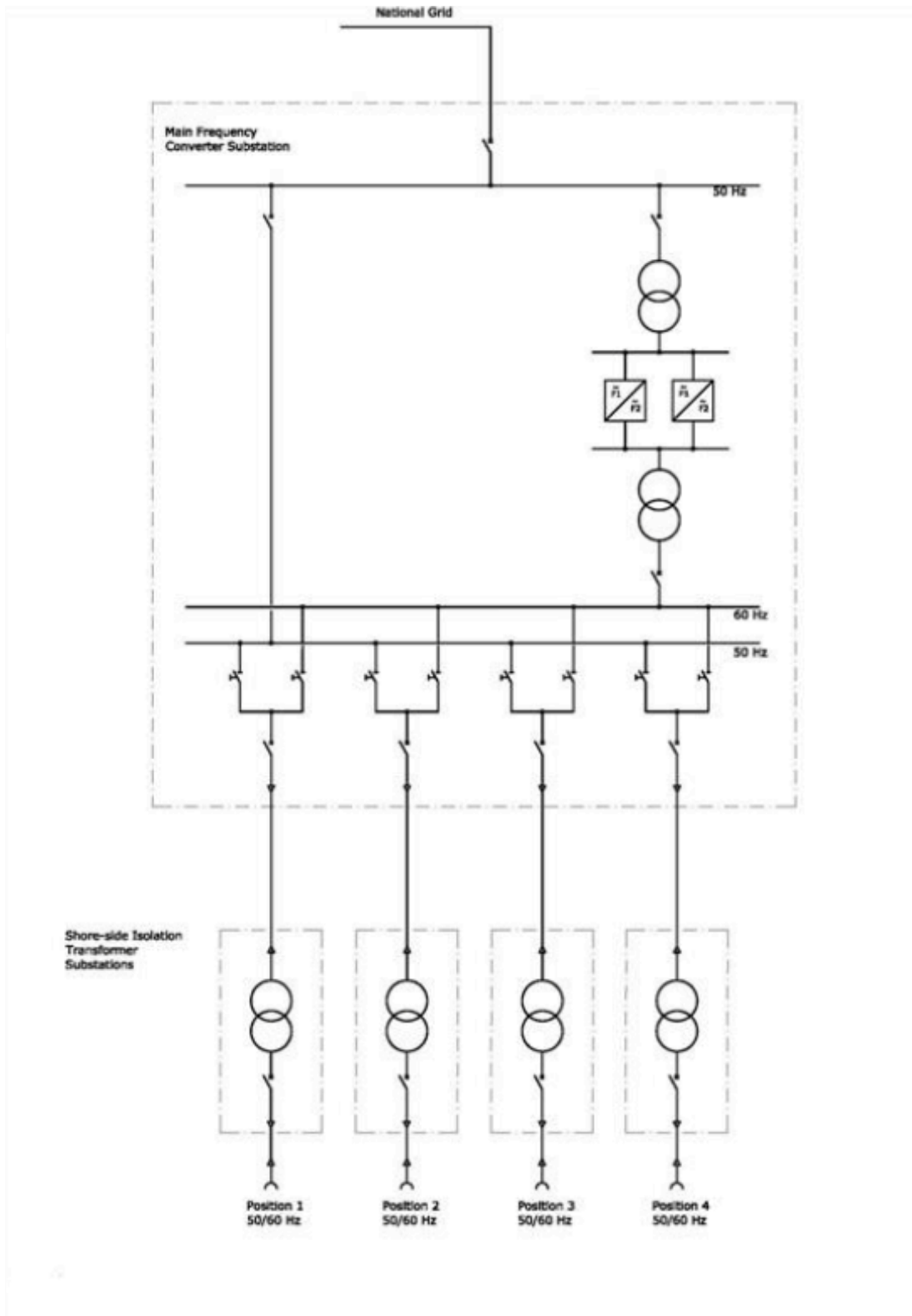
Figure 4: Electrical drawing of proposed centralized configuration (2)

3.2 Equipment

So for this configuration, a set of equipment is needed which consists of Frequency Converters, Voltage Transformers, Double Busbar Systems, Switchgears, Circuit Breakers, Cables and Connection Boxes as well as equipment onboard the vessel.

Frequency Converters are responsible for making compatible ACs of different frequency and specifically convert 50Hz to 60Hz and vice-versa.

Voltage Transformers transform the voltage from the onshore grid to the input voltage of the vessel. Except the voltage transformer's connection with the frequency converter (both as an input and as an output), a voltage transformer with a 1:1 ratio is used as an intermediate equipment to the connection of the 50 Hz busbar with the national grid following the Ericsson's – Fazlagić's configuration scope. (2)

Double Busbar Systems allow the simultaneous use of 50Hz and 60Hz AC to each of the berth's terminal.

The **Switchgears**, **Circuit Breakers**, **Cables** and **Connection Boxes** are all used for matters of safety and good performance in order to avoid misbehavior or damage in the whole system.

Figure 5: 1. Frequency Converter PCS 6000, 2. Voltage Transformer, 3. Double Busbar Unigear ZS1 (4) (5)

3.3 World Facts

For the sake of adequacy some facts of the world's current state concerning Cold-Ironing are presented here.

At the moment Cold-Ironing has expanded as a technology in numerous ports most of which are listed below:

- Antwerp – Belgium
- Zeebrugge – Belgium
- Prince Rupert – Canada
- Waigaoqiao, Shanghai – China
- Kotka – Finland
- Oulu – Finland
- Kemi – Finland
- Marseille – France
- Hamburg – Germany
- Lubeck – Germany
- Kyllini – Greece
- Livorno – Italy
- Rotterdam – Netherlands
- Oslo – Norway
- Bergen – Norway
- Gotenborg – Sweden
- Stockholm – Sweden
- Helsingborg – Sweden
- Pitea – Sweden
- Los Angeles – USA
- Long Beach – USA
- Seattle – USA
- San Francisco – USA
- Pittsburg – USA
- Juneau – USA
- San Diego – USA

Although an in-depth analysis is not in the scope of this thesis a quick example is given regarding the needs of the Passenger Vessels that anchor in the port of Peiraeus – Greece (6):

Vessel Name	D/G Number	D/G Output	Hotel Load (kVA)	Voltage (V)	Frequency (Hz)
FESTOS PALACE	3	2250	3122	380	60
KNOSSOS PALACE	3	2250	3122	380	60
BLUE STAR DELOS	3	1320	1832	-	50
BLUE STAR PATMOS	3	1320	1832	-	50
BLUE STAR PAROS	3	1160	1610	380	50
BLUE STAR NAXOS	3	1160	1610	380	50
BLUE GALAXY	3	1000	1388	-	60
BLUE HORIZON	4	1240	2294	450	60
BLUE STAR 1	3	1260	1748	440	60
BLUE STAR 2	3	1260	1748	440	60
NISSOS MYKONOS	3	1080	1499	380-415	50
NISSOS RODOS	3	1000	1388	440	60
KYDON	3	1000	1388	-	-
SUPERFAST XII	3	2000	2775	-	60
ARIADNE	3	1100	2035	440	60
	1	1100			

Table 1: Peiraeus Passenger Vessels Hotelling Needs at Port (6)

3.4 Cold-Ironing Analysis Calculation

The purpose of the analysis has been to provide the user with enough information as to if a cold-ironing implementation on an already operating port would be viable and profitable. The main methodology used for this analysis consists of 4 pieces.

The implementation of a Shore-to-Ship technology is done in a port. So addressing a port is the first thing that needs to be done. The first attribute as an input is the distance from the national grid to the port's Main Substation from where the power will be distributed.

The distribution to the ships needs to be done for each berthplace on its own. So depending on the number of berth places that we have and the type of vessel that each berthplace will accommodate.

At this point the number of berth places, the type of vessel of each berth place as well as the Current Voltage, Power Output and Voltage Transformer of each berth place are needed as input data.

Voltage Transformers as data need a wide variety of specifications from which here are needed only the Rated Power, High and Low Voltage.

Frequency Converters meanwhile require a Power Output, an occupied area (m^2) and a Voltage Transformer Area (m^2)

For each type of vessel now there is a preset number of berth places and what needs to be done is to register the amount of cable and connection boxes that the port needs to have in order to serve that type of vessel. The cables are divided in 6.6kV, 11kV and 20kV cables. 20kV cables correspond to the cables connecting the main substation to the berth places whereas 6.6kV and 11kV cables are the ones that connect the shore side substation to the connection boxes.

Subsequently, a Voltage Transformer and some Frequency converters need to be registered in the port for each berth place.

Once everything is set 4 different fields of information are calculated, all concerning costs:
1. Main Substation
    a. Cable
    b. Buildings
    c. Frequency Converters
    d. Voltage Transformers
    e. Double Busbar

       f.   Switchgears, Circuit Breakers, Cables

       g.   Cooling, Ventilation, Fire Detection, Lighting, Alarm

2. Primary Cable Arrangement (Distances)

3. Shore-Side Station

       a.   Buildings Voltage Transformers

       b.   Switchgears, Circuit Breakers, Cables

4. Shore-Side Connection Arrangement

       a.   Connection Boxes

       b.   Cables

This cost breakdown is intended to assist in the planning stage of such a project-investment and notably more if the given results are concentrated and the data manageable.

4. Tools for Web Development

4.1 General Information

The World Wide Web (www), invented in 1989 by Tim Berners-Lee, also known as the Web, is a system for distributing information across the world through the internet. As its own name proposes, it is a web that connects every piece of information through Uniform Resource Locators (URLs, e.g. http://www.some-address.com). This means that anyone can access any piece of web resource addressed under a URL, simply by knowing that URL. (7)

Today the world wide web is a growing monster with growing rates that none has ever seen before, mainly due to the fact that it is accessible by the vast majority of the population, the contribution is free and everyone accesses basically the same place, the web. In Figure 6, a map of the global contribution to the world wide web is presented.

In order to be able to establish a connection to the URL and access all of its addressed information a web browser is essential. Web browsers were built around 1990 and became widely known and used by 1994. (7) Today a web browser (e.g. Google Chrome, Safari, Opera, Internet Explorer) is arguably the most common application used by an everyday computer or smartphone user. It mainly gives a user the ability to access any web page he would like.
Compared to the birth days of web browsers, today the capabilities of these applications have evolved significantly, resulting in a much more user friendly, functional, high-performing and fast application. The evolution of web browsers has made the experience of "surfing" the internet almost a joy for some people while at the same time, a truly powerful tool for developers to build environments that will feature far more than just a static page with some text.

In general, the structure and functionality of the world wide web starts with and relies on the existence of a web server.
A web server is a computer (implementing both hardware and software) where all of the data of websites is stored. It has the ability, by utilizing a special protocol called Hypertext Transfer Protocol (HTTP, hence the http prefix in a URL), to respond to requests and transfer data from and to the client making the request (e.g. personal computer). Nowadays more and more an enriched variant is being used, the HTTPS protocol (the "S" extension stands for secure) which adds a layer of security by protecting the transferred data from not being readable by anyone else except the client.
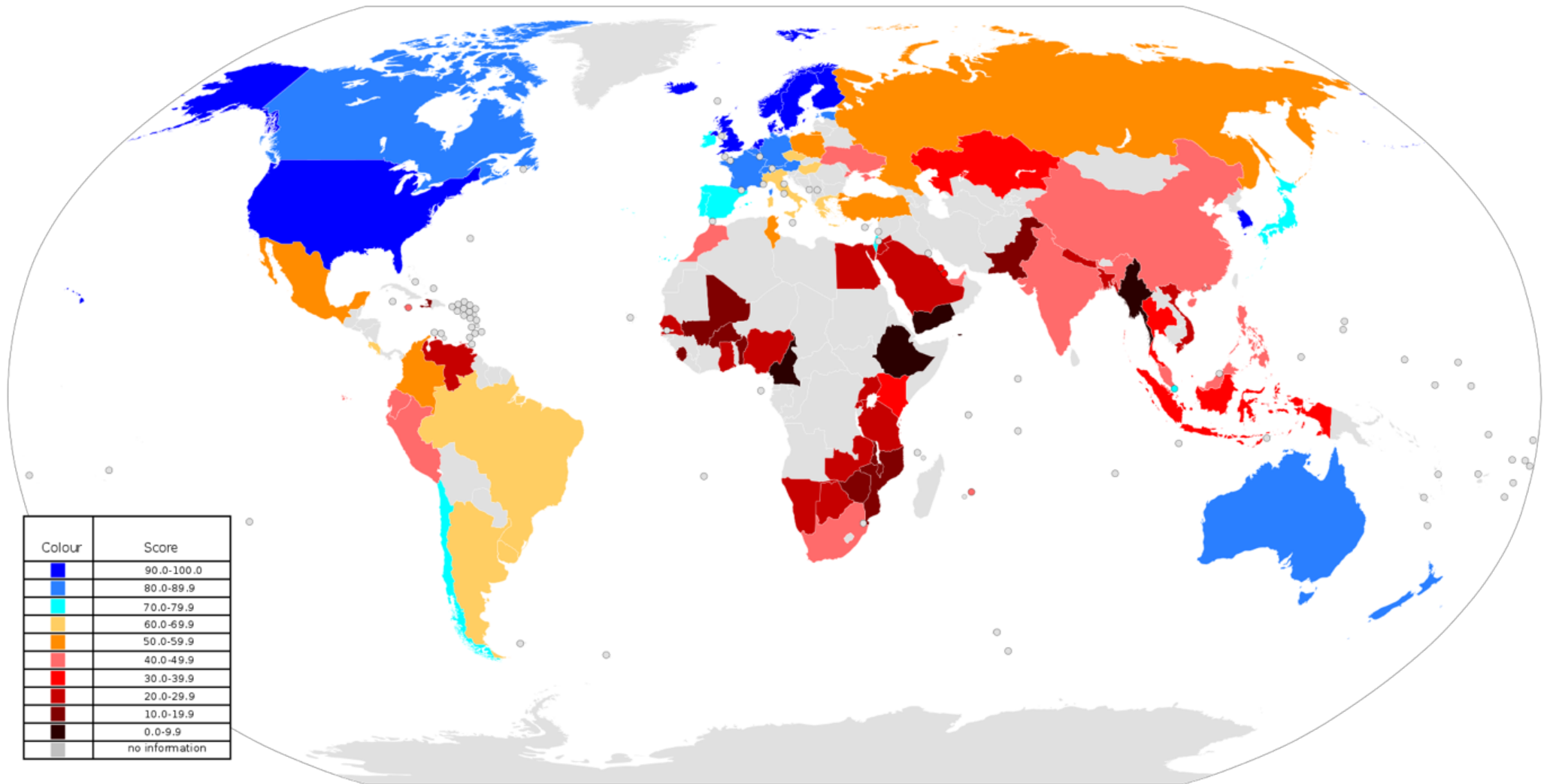
Figure 6: Map of Web Index[1] (2014) (7)

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[1] Web Index is a multi-dimensional measure of the contribution of each country to the world wide web in terms of development and human rights (7).

Once the data has been transferred and collected it is the client's job to interpret them. The resources that a web server stores consists of:

- **Databases**, which are structures that store tables of data highly manageable and accessible
- **Media files**, which are all the images, videos that can be downloaded or presented on the web page.
- **Downloadable files** of any kind (pdf, docx, applications etc.)
- And lastly the most important part, **code files**. Namely all the files that contain the code which needs to be ran in order for the web page to function, may that contain the design, the functionality or the security of a web page.

Regarding code files, they are the first thing accessed by the web browser. The Browser then in terms through its interpreting capabilities reads and "executes" those files with the help of the server and eventually the result is presented inside the web browser interface. In essence a web browser is the application from which a computer/smartphone sends a request to a server through its address (URL). The server sends back all the files that have been requested and the browser translates those code files into a graphical interface for the user to navigate in.

4.2 Languages

The abovementioned code files consist of a wide variety of files. With the development of the web, browsers also gained capabilities which include the translation of different language at the same time. Meanwhile the parts that a web browser cannot interpret, are instead ran in the server and the data is sent raw to the client.

The code that is written to build a web page is composed of different programming languages. Web Development Languages are categorized depending on whether they are ran on the client side or the server side, namely front-end and back-end languages.

Front-end web development, also known as client-side development is the practice of writing code through the use of HTML, CSS, and Javascript languages in order to create a graphical interface that a user can interact with. It is mandatory to any web page to build a client-side otherwise there is nothing for a user to use. These languages run directly in a web browser on the client-side without the help of a server, apart from getting access to the code itself.

HTML (Hyper Text Markup Language) is the core of any website development. Without HTML there is no website at all. It was developed by the same person that invented the web, Tim Berners-Lee.

Hyper Text implies that the use of hyper links is possible. Through HTML links can be created that navigate you to other pages of a web site or other pages of the web in general. Markup indicates that all code written, if written accordingly, can create objects such as tables, shapes, image frames, video frames etc. HTML is solely used for front-end web development and is the first language built for it. Today the language has been developed a lot compared to the first version. With numerous version taking place, the most recent one is HTML5 published on 28 October 2014 (7).

An example of HTML code is shown below in figure 7 (on the left) with its result in the web browser (on the right). As shown, the code consists of enclosing blocks of code with the double arrows "<..>" implying the start of a block and the double arrows with slash "</..>" implying the end of that block.


```
<!DOCTYPE html>
<html>
<body>

<h1>My First Heading</h1>

<p>My first paragraph.</p>

</body>
</html>
```

My First Heading

My first paragraph.

Figure 7: HTML Example of A Simple page (Result in a web browser on the right)

As the example above dictates raw html code may provide the data but not in any pretty way. Let's say that it creates a presentation but in an all black one font kind of style. Not only marking managers but simple users are drawn by the opportunity of an elegant, pleasant environment. The resolution to this problem is CSS.

Cascading Style Sheets (CSS) is a language used for "decorating" a markup language such as HTML. It dictates to the HTML document how the items should be presented. CSS was initially release in 17 December 1996. (7) The capabilities of CSS are enormous, with features such as: text styling, colors, backgrounds, user interaction decoration etc. CSS files have the .css extension they are usually stored in folders of the website and are addressed directly from the html document.

An example of some difference made by a simple piece of CSS code is shown below. The exact same HTML document was used as in figure 7, except this time some CSS styling was added. The grey background, round corners, dark blue, center-aligned, Arial heading and center-aligned underlined, italic style, Arial paragraph are right away noticed.
The example might be very simple but the power of CSS truly great and mandatory nowadays.

Figure 8: Simple HTML with some CSS (Result in a web browser)

The third part needed to complete a front-end development is the ability to add functionality to different actions that a user might take as well as functionality around non static objects in the page. This addition has become available with the introduction of Javascript into web development. Web browsers are capable of running Javascript natively, thus giving developers a great opportunity for enhancing the website's experience.

Javascript (JS) is an object-oriented, high-level language invented in December 1995. Javascript and Java are often confused but these two languages do not have the same origin. Javascript consists of a programming language for scripting with similar syntax to C.

Below a simple example of a Javascript function is presented with a button making a change in real time of some text in the web page.
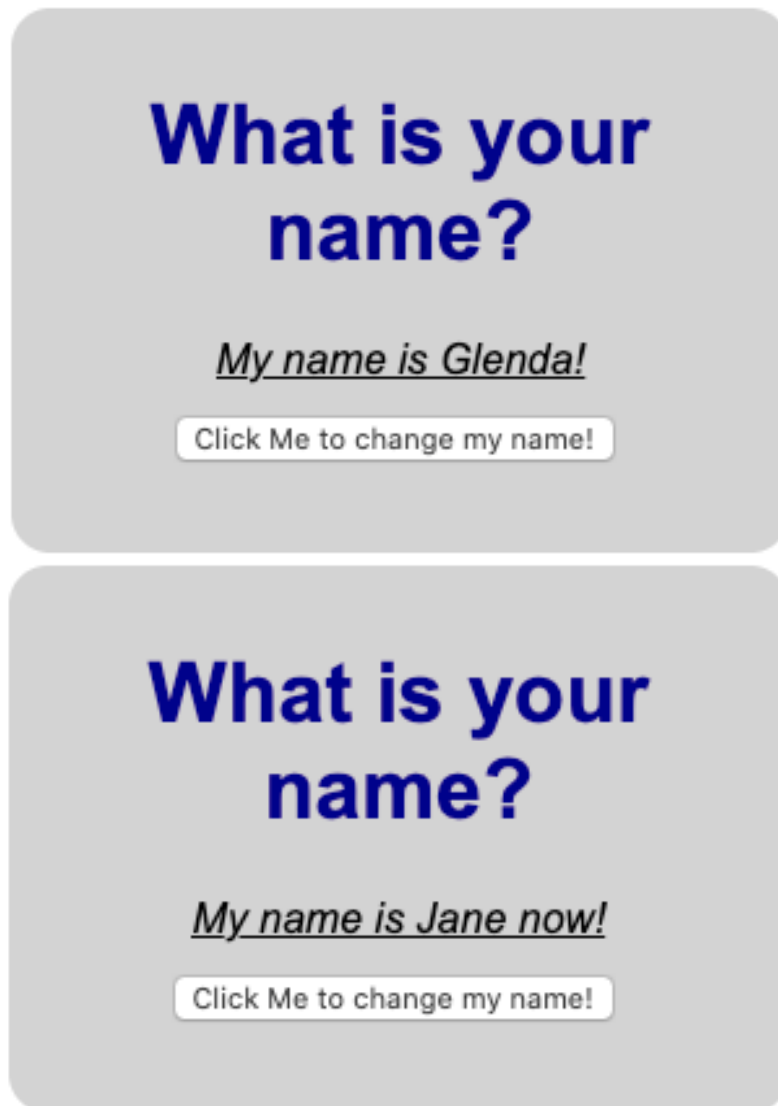
Figure 9: Result after clicking a button with Javascript code behind it

So in front-end development all of the user-website interaction is written and all the graphical interface is generated. However modern websites utilize a variety of tools in order to add extra functionality which may include calculations, authorization, intelligent tasking such as online applications, saving and loading data online and more. These tasks are handled by the second category of web development, called back-end.

Back-end development is responsible for all the server-side tasking utilized in a website. The code written runs on the server and all of the application logic is built here. Although a static website can be built solely by using front-end development, its use would be minimal, thus making back-end development the field of power for today's website development. The back-end contains all the functionality in any online application without any fanfare and establishes a solid connection with the front-end in order to present all of the work done.

In back-end development a different set of languages is used. Depending on the tasks that have to be accomplished, languages here are categorized in functional and database management languages.

Databases use their own set of languages. Specifically database operate through a database management system which is a software systems that gives users the control over the database. Popular examples of DBM systems are: MySQL, SQLite, PostgreSQL etc. These systems have been developed in the scope of making databases more powerful, faster and larger.

All of the data, no matter where that is, is handled by the server with functions written in traditional programming languages may that be object-oriented or not. Some of the languages used in web development today were not invented strictly for web development but have grown to be of great popularity and power to web developers. The languages used primarily as of 2020 are Python, Ruby, Java, PHP, C++, C.

Every single language has some very powerful tools to offer depending on what the developer intends to do. In this dissertation PHP was widely used.

PHP is a general-purpose scripting language especially suited for back-end web development It was created by Rasmus Lerdorf in 1994. It is a widely ported language that can be deployed on most servers and run on any operating system and platform thus making it a brilliant choice for a versatile website. It has run 8 different versions by the time of writing, with the latest being release in January 2021. (7) A feature that makes PHP ideal for web-development is that it can be embed in HTML documents, which means that at any moment back-end functions can be called directly from front-end documents. In addition, newer versions include the ability to access database without writing raw database code (e.g. MySQL).

Therefore with all this information in mind it is clear that in order to build a modern website a variety of different languages need to be used. The problems of complexity and plethora of code files and languages arise. In that scope developers have built and used frameworks in order to handle the situation.

A web framework is a set of tools that aim to support the development of web applications. Most web frameworks provide libraries and templates so that to make the work of a developer somewhat automated in aspects that code can be reused. There are different types of frameworks in terms of architecture as well as client/server-side differentiation. In

addition every framework utilizes a different programming language as a basis while adding its own libraries, templates and models with their unique set of functions and dictionaries. Some of the most popular frameworks with their basis language today are: Rails (Ruby), Django (Python), Angular (Javascript), Laravel (PHP), CakePHP (PHP), Express (Javascript), Vue (Javascript), React (Javascript), etc.

Framework	Github Score	Stack Overflow Score	Overall Score
React	99	97	98
ASP.NET MVC		95	95
Angular	91	96	93
Ruby on Rails	87	99	93
AngularJS	90	97	93
Vue.js	100	87	93
Django	89	97	93
Laravel	90	93	91
ASP.NET	80	100	90
Spring	86	94	90
Express	88	87	87
Flask	89	83	86
Meteor	86	80	83
Symfony	81	86	83
CodeIgniter	79	86	82
JSF		81	81
Ember.js	80	78	79
.NET Core	77	80	78
Google Web Toolkit		77	77
CakePHP	72	80	76

Figure 10: Web Framework popularity by Github and Stack Overflow rankings (2021) (8)
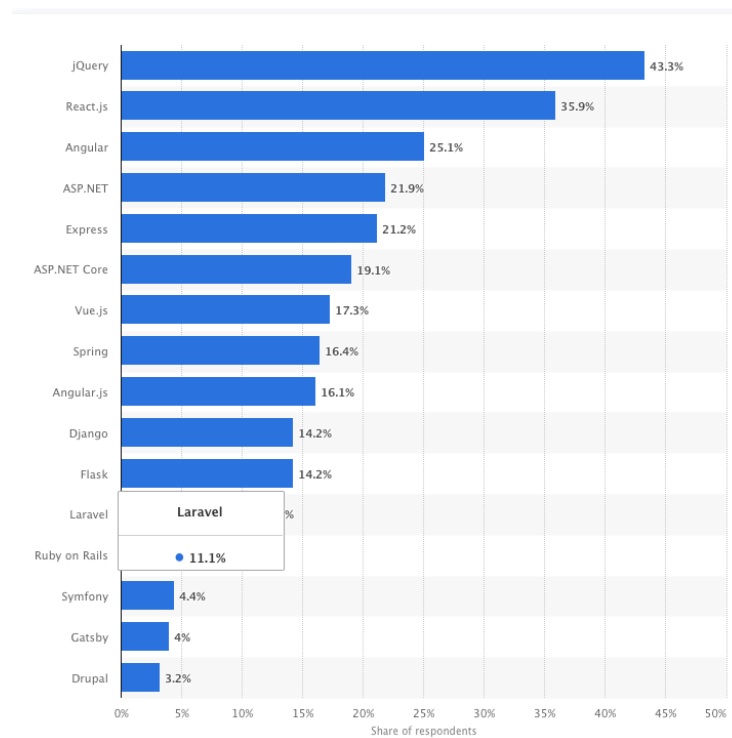
Figure 11: Web Framework popularity (Early 2020) (9)

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Website	Popularity (unique visitors/month)	Front-end (client-side)	Back-end(server-side)	Database	Notes
Google	1,600,000,000	Javascript, Typescript	C, C++, Go, Java, Python, Node	Bigtable, MariaDB	The most used search engine in the world
Facebook	1,100,000,000	Javascript,Flow	Hack, PHP, Python, C++, Java, Erlang, D, XHP, Haskell	MariaDB, MySQL, Hbase, Cassandra	The most visited social networking site
YouTube	1,100,000,000	Javascript	C, C++, Python, Java, Go	Vitess, Bigtable, MariaDB	The most visited video sharing site
Yahoo	750,000,000	Javascript	PHP	PostgreSQL, RDS, RDS Aurora	One of the largest search engines and news feed websites
Amazon	500,000,000	Javascript	Java, C++, Perl	MariaDB	Popular Internet shopping site
Wikipedia	475,000,000	Javascript	PHP	MySQL	The most popular online encyclopedia
Twitter	290,000,000	Javascript	C++, Java, Scala, Ruby	Microsoft SQL Server, CosmosDB	Popular social networkd
Bing	285,000,000	Javascript	C++, C	Orable Database	Seach engine by Microsoft
eBay	285,000,000	Javascript	Java, Javascript, Scala	Microsoft SQL Server	Online auction house
MSN	280,000,000	Javascript	C#	Voldemort	Email client
LinkedIn	260,000,000	Javascript	Java, Javascript, Scala	MySQL, Redis	World's largest professional network
Pinterest	250,000,000	Javascript	Python, Erlang		Search engine for ideas

Table 2: Programming languages used in the most popular websites

4.3 Hosts/Servers

As previously mentioned, a website's resources, such as the code, media files and databases are all stored in a server from where they are requested by each client. A developer means can create all that data and make a website functional. However, he may not necessarily possess a web server where all the data can be stored. In order for a website to be deployed a web host service is needed.

A web hosting service is a tool that allows individuals or organizations to upload their website and make it accessible to the web. They provide space in a web server where all website data can be stored as well as connectivity to the internet so users can access the website through it.

There are and have been numerous web hosting services provided either for free or with cost. Each of them provides a different set of tools and the servers of them different capabilities. Reliability of web hosts and uptime of a server may vary depending on the quality of services provided by each web hosting company.

Some key features that a web host may provide are:
- Ability to run other languages than PHP. This means they have installed the appropriate interpreter for that particular language
- Access to a terminal (Command Line) in order to make such installations as above or manipulate your website through it
- A File Manager with a user friendly graphical interface that lets you manipulate all the files of the website
- A phpMyAdmin environment where all of the databases can be managed through a graphical interface
- An email service, through which your website can send emails to clients
- Ability to natively host a CMS (Content Management System, explanation out of scope) website
- Good uptime
- Good pricing etc.

Among the most popular web hosting services today are A2Hosting, Bluehost, Dreamhost, Hostinger, GoDaddy. Worth mentioning is the Greek web host Papaki.
Big organizations like tech companies, governments, universities etc. usually utilize their own servers and self-host their websites.

4.3 Constraints & Needs

In the making of a web application the environment in which it is going to be set up (host), the target functionality that has been set, the familiarity of the developer with languages as well as the size and speed that is demanded, propose the needs and constraints of the project.

The current web application has been created in the context of a diploma thesis as part of the studies in the National Technical University of Athens. At the same time, its content closely associates with the university, its studies and personnel. Consequently, a space has been provided by the university's network center (par. 4.4).
Other alternatives could be evaluated, however, the quality of services provided by the university, combined with its suitable URL suffix (.naval.ntua.gr) for such a website and the fact that it was freely provided to members of the university community made it the appropriate choice.
Despite the benefits of this choice, the first noticeable constraint posed with the fact that there were no extra included interpreters leading to the limited capability of building the back-end of the website in PHP.

In the meantime, the website would support two applications bonded with database usage, and user authorization, as well as a number of static pages. These facts made the use of a framework appealing or even mandatory.

4.4 Network Center (NTUA)

As above mentioned, the hosting of the website has been provided by the Network Center of the NTUA.
NTUA's Network Center is a unit of NTUA, which has undertaken the obligations of organizing and operation of the Telematics Network (Voice & Data) of the University. These obligations include the compliance of specifications of a unified structured cable infrastructure, the installation and operation of the active equipment and the development, installation and support of the telephone network and data network services in the NTUA. (10)

Some of the services that it provides to users are:
- Wi-Fi
- Website for university classes (mycourses)
- VPN
- E-mail Client etc.

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While it provides to admins:
- DNS
- Virtual DNS
- Web Hosting
- Virtual E-mail
- SMTP
- SSO
- Server Hosting
- NTP etc. (10)

The NTUA Network Center (www.noc.ntua.gr) assembles a very organized and solid service provider with full support to all of its community.

4.5 Research for the Tools

Given the needs, constraints and web host of the web application a research had to be done on which tools were going to be used in order to support the making of it.
The research focused on finding the best framework encapsulating the appropriate language (PHP) and functionality.
It is worth mentioning that the knowledge and use of the framework were not possessed so an adequate documentation would also be mandatory along with PHP, HTML, CSS and Javascript knowledge.

Meanwhile other tools that are mandatory for such a project are:
- A powerful text editor. The amount of code needed to be written exceeded 100MB in simple text files which translates to thousands of lines of code, around a hundred self-created files and hundreds of pre-existing files in libraries. That imposed the need for a text editor capable of handling that amount of data
- Server/Networking tools. During building the application, the result had to be visible in order for tests to take place. However, during development it is bad practice to have the website live in debug mode. A local server had to be set up in order to accommodate in early stages so that it would only be accessible to the developer.
- Finally, a backup tool for the code in order to maintain data safety and version control of the development stages.

4.5 Laravel

Laravel is a free open-source PHP web framework, created by Taylor Otwell and licensed under MIT licensing. Its scope is the development of web applications under the Model-View-Controller (MVC) architecture. This means that there is a model for each set of data, a controller that handles that model and a view that presents the results of that model-controller.

Laravel features libraries and a dependency manager that handles all of these libraries and any libraries needed to be added during the development. A dependency manager is a feature that allows the user to automate the installation of libraries, addons and their dependencies with a simple series of commands usually through command line.

Figure 12: Laravel logo

Laravel has a bundle of internal features like Eloquent, Blade, Homestead, Canvas etc.

Eloquent for instance, provides ways of manipulating databases and connecting the data, while at the same time Controllers promote the ability to easily transfer the data to the front-end of the application.

With Blade the front-end can be supported with the creation of templates and data can be manipulated and presented to the view.

The creation of databases and tables becomes more sophisticated with the Migrations feature of Laravel providing details and connections between the database and the model in Laravel.

Queries to the databases, application logic and controllers handling HTTP requests are all part of the bundle of features that Laravel provides.

One of its main advantages is that it is scalable. Meaning that a project can get very large and still be supported and handled. The community of users of Laravel is large enough to provide extra functionality through third-party libraries. At the same time there is an adequate documentation providing a lot of necessary information to build a web application.

It is supported on all operating systems and platforms and has ran a lot of versions up to the newest being Laravel 8.

4.6 Sublime Text

The lines of code in a development project can grow enough to make a developer not know what he has actually build from a point on. Even more confusing can be putting the files together and opening the files needed in the appropriate place. An example from this dissertation is the user authentication feature which alone needed 12 different files written by the developer and some other files generated by the dependency manager feature of the Laravel framework. Meanwhile the largest file in lines of code surpassed 800 lines.

It is obvious that a software support is required in order to put everything in order and make the code readable (fig. 13). In this case Sublime Text was used.

```php
public function create()
{
    $user = Auth::user();
    $data = request()->validate($this->validationArray);
        $data['user_id']=$user->id;

    VoltageTransformer::create($data);

    return redirect('apps/voltagetransformers');
}
```

```php
public function create()
{
    $user = Auth::user();
    $data = request()->validate($this->validationArray);
    $data['user_id']=$user->id;

    VoltageTransformer::create($data);

    return redirect('apps/voltagetransformers');
}
```

Figure 13: Readability difference between a common Text-Editor and Sublime-Text

Sublime Text is a shareware source code editor. It supports a wide variety of programming and markup languages including PHP, HTML, CSS and Javascript while it includes a dedicated Python API.

It supports the opening and saving of a project through a special feature with the use of a dedicated file with the suffix ".sublime-project". That means that it can open a project inside a folder and present the whole project tree of folders and files inside the text-editor in a column (fig. 14).
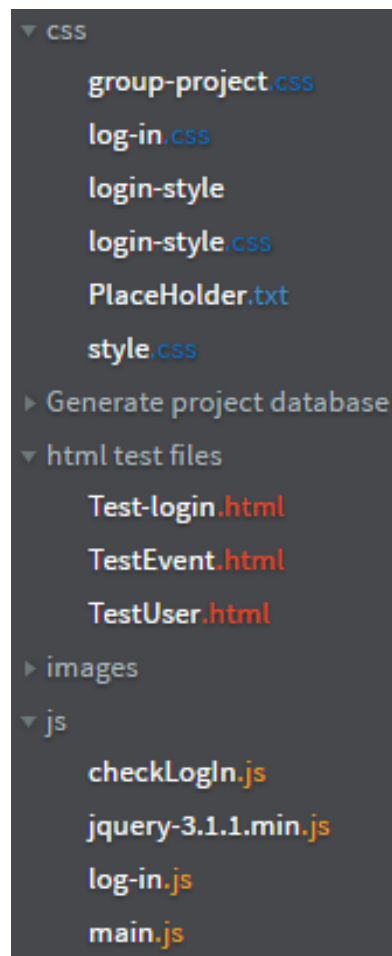
Figure 14: Sublime-Text sidebar project tree example (11)

Sublime Text offers the ability to handle large portions of text or repetitive text with finding and replacing features and even a RegEx-ready (Regular Expression) environment for a more efficient way of manipulating text. A Regular Expression is a sequence of characters that define a search pattern. (7) RegEx provides among other features an intelligent way of finding and replacing text while the whole process is handled by algorithms built in application like Sublime Text.

4.7 MAMP

A local server was required to build and run the website any time without having the website uploaded. A computer by itself cannot open websites with server-side functionality and/or databases. For this reason special software has been built to deploy a local server on a personal computer.
Regarding this project, the development was done on a MacOS computer, thus the software used was MAMP.

MAMP stands for MacOS, Apache, MySQL/MariaDB, PHP/Perl/Python.
It is a free, local server environment capable of running on both Mac and Windows operating systems. It supports MySQL and MariaDb databases, Apache or Nginx web servers and four major back-end development languages: Python, PHP, Perl, Ruby. It also provides the user with a phpMyAdmin environment.

There is also a PRO version with extra functionality and features, however it comes at a cost
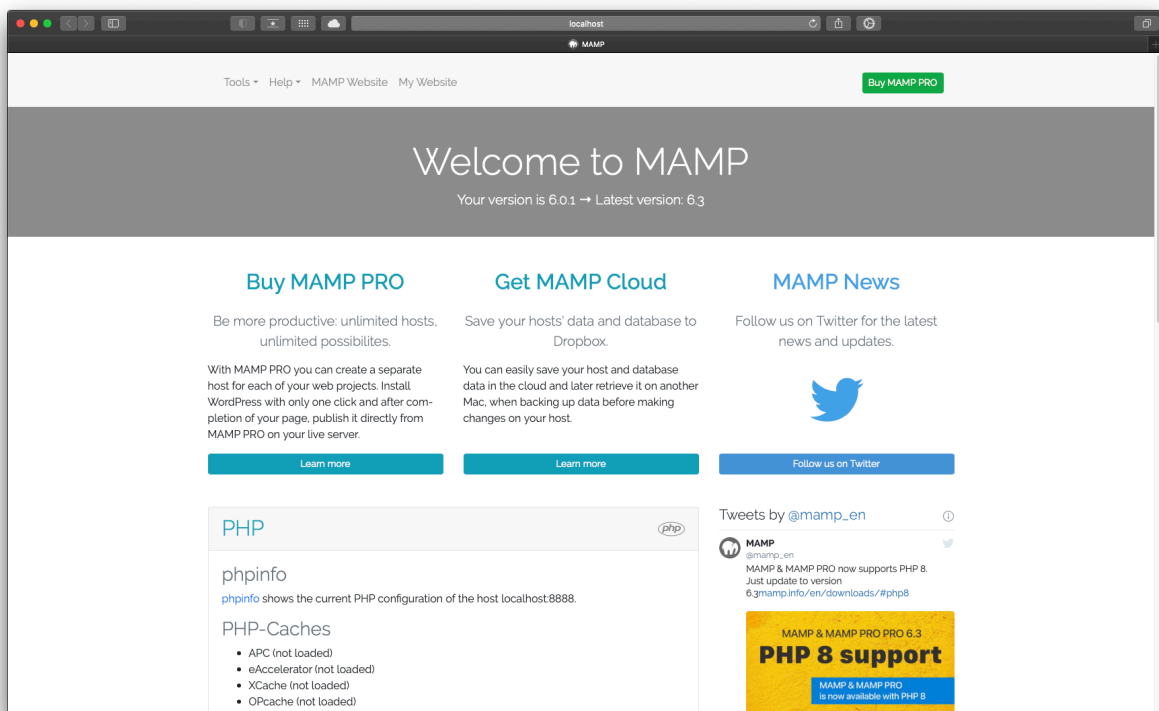
Figure 15: MAMP WebStart page on MacOS

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4.8 Git/Github

The process of building and maintaining an application regardless of the type of application is long lasting. Apparently, for as long as the application is live or gets updates the process is still going on. A lot of versions and code is written by one or more developers. Meanwhile there are attempts to develop in a way that eventually is not preferred and things might need to go back.
In order to keep control of the complexity of this process a large amount of backups are needed as well as a log of different attempts and version of each of the backups. This whole process is supported by Git.

Git is a distributed version-control system for tracking changes in any set of files. It was originally created for organizations consisting of more than one developer to keep control of distributed, non-linear workflows. Git was created by Linus Torvalds in 2005 for development of the Linux kernel, with other linux kernel developers contributing to its initial development. It is mainly used through command line. (7)

Git gives the opportunity to keep different backups in your own directory without them being visible unless accessed through special commands in the command line. Each backup is designated by its own name (Usually a git-generated string. A preferred name can be used as well) and can be recalled at any point.
Every backup is a version, and the user can go back and forth to different versions at will. Whenever necessary a previous version could become the main version again while new branches can be created to make tries, keep them or discard them and return to the main branch. Branches can also be used to develop in parallel different parts of a project and eventually merge them back again.

Data stored on a personal computer remains at risk in a possible damage of the computer. Hence the use of an online platform that stores all of this Git data promotes safety of the project and concurrently access by any computer authorized with access to the world wide web.

One of the most popular platforms performing such a task is Github.

Github is a subsidiary of Microsoft which provides hosting for software development and version control using Git. It offers distributed version control and source code management (SCM) functionality of Git. It was launched in 10 April 2008 and developed by Chris Wanstrath, P. J. Hyett, tom Preston-Werner and Scott Chacon and today has over 40 million users and more than 190 million repositories. It is offered for free to the users and the community of it offers software for free through Github. (7)

5. Building the Web Application

5.1 Study & Setting up the environment

The first step to building the project was to get foundation on the tools that would be used and to research in detail the functionality of the apps.

Thanks to the vast documentation of the internet a fast-paced gathering of the required knowledge and information was possible. A first dummy project was built with Laravel, with numerous tries on different aspects of the project. Meanwhile, familiarity with databases, server operation and the text-editor was mandatory all of which was done with the help of research in developers' communities, tutorials and documentation available in the web.

With reference to Mr. Diavatis and Mr. Michails' dissertations an outline of the scope of the apps and the main functionality was created, as mentioned in chapter 3 of this dissertation.

The first steps taken in the making of the applications was setting up the environment.
All of the software used as mentioned in chapter 4 was installed. MAMP and Sublime Text were installed through graphical interface whereas Laravel through Command Line.

It is not in the scope of this dissertation to explain every programming technique and aspect of the job done so a brief explanation of each will be done where necessary.

5.2 The Graphical User Interface

As previously mentioned every aspect of the application has to be linked to a model, which is controlled by a controller and presented in a view. Views contain of objects of one or more models but also contain the graphical interface of the website itself.

With the help of Blade (see 4.5) the ability to create a base template of the website structure was provided.

Although the creation of the apps preceded the creation of the static pages it was deemed mandatory to first create a base GUI and its style in order to build on it from there on.

At this point HTML and CSS where mainly used. It is worth mentioning that the whole site has been built with a scope to versatility, thus a double work was done for usage on mobile devices and small screens in addition to regular desktop and laptop screens. Every design aspect was modified so that the user experience on any device would be as friendly as possible.

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First and foremost, a navigation bar was created in the header of the webpage. As set by the goals of this dissertation the navigation pane had to include:

- Homepage
- CV (Biography)
- Courses Offered
- Publications
- Books
- Laboratory Unit
- Research action and programs
- Apps

With the use of CSS an adequate height was given for readability in addition to a mouseover and current page effect with a different color as shown in (fig.16).
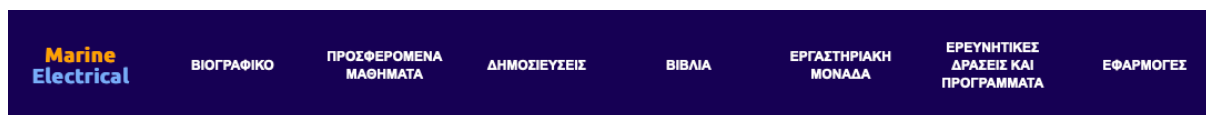
Figure 16: Navigation bar of Marine-Electrical (Desktop)

By clicking on any of the links in the navigation bar the user gets redirected to the corresponding page of the website.

On a mobile device such a wide navigation bar would be difficult to read and use so a dropdown menu replaced the desktop version (fig. 17).

Figure 17: Navigation menu of Marine-Electrical (Mobile Screen)

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Accordingly, the footer of the website was designed with a reference to the Services provided by the website and a Communication field with all the information of the lab and office of professor J. Prousalidis.
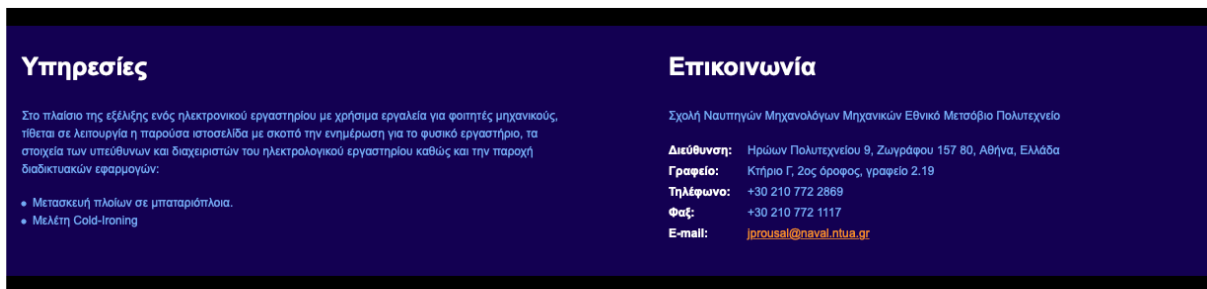
Figure 18: Footer of Marine-Electrical (Desktop)
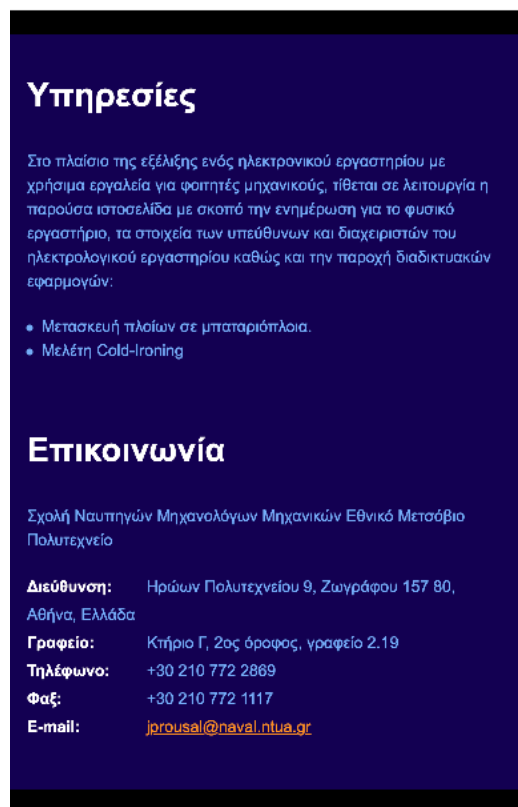
Figure 19: Footer of Marine-Electrical (Mobile Screen)

The body of each of the pages linked by the navigation pane were created after the creation of the two basic applications as stated in chapter 1.

5.3 Applications

By clicking on the Apps button in the navigation (fig. 20)
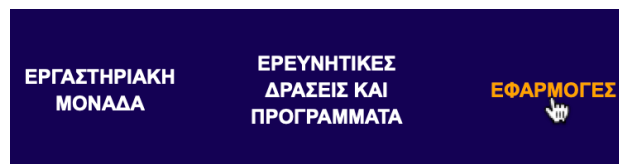
Figure 20

The first view that the user sees is that of the user authentication. (fig. 21):
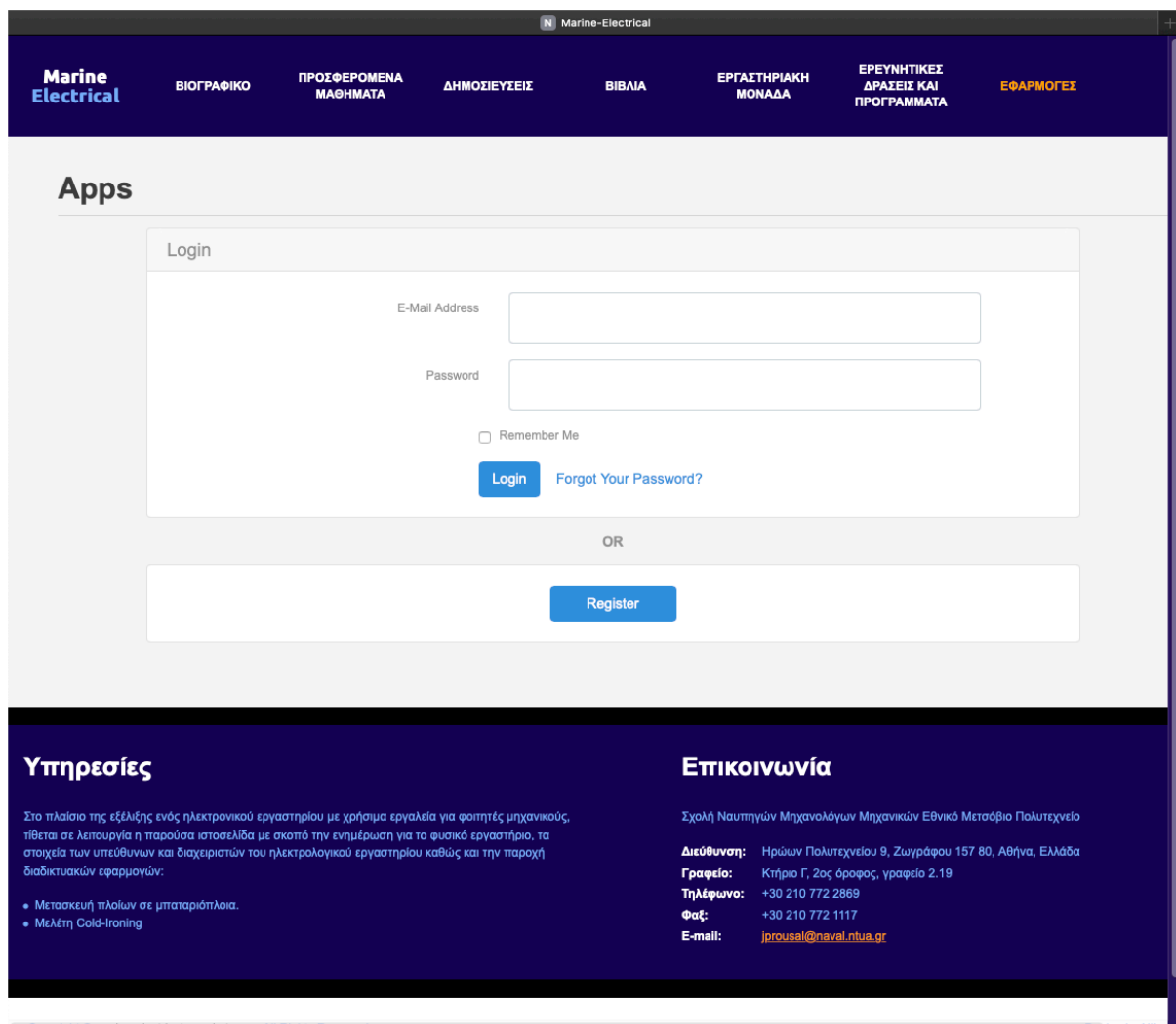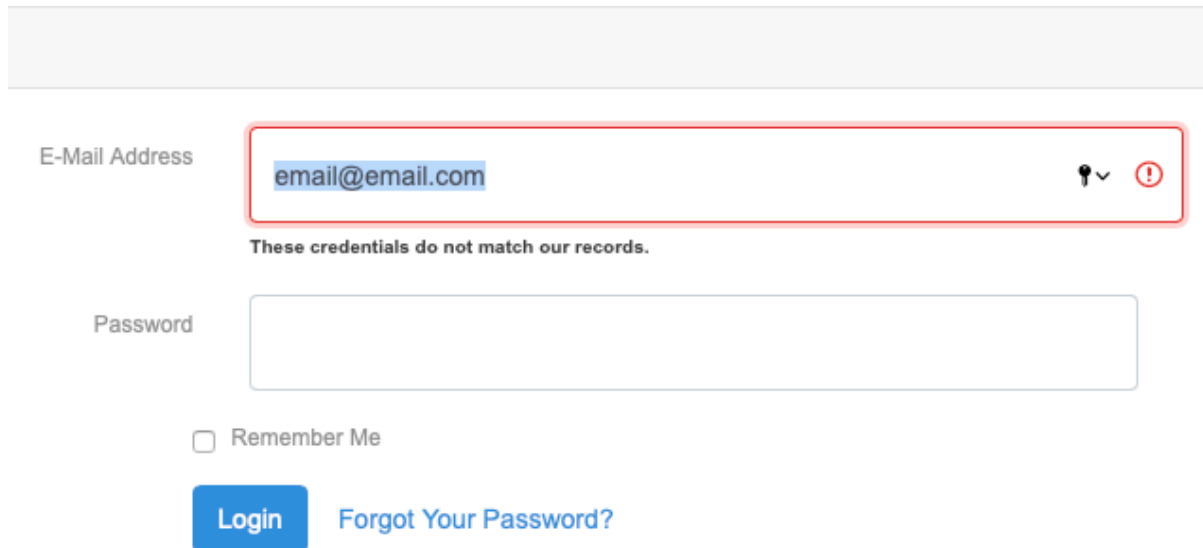
Figure 21: User Authentication View in Marine-Elecrical

Through this page a user can Login to his/her unique account. By filling the credentials Email Address and Password and clicking Login an authentication check is ran in the server. If the

user exists and the credentials are correct then the authentication is successful and access to the Apps is gained. Otherwise a message is shown: "These credentials do not match our records" (fig. 22)

Figure 22: Message "These credentials do not match our records"message shown after failed login attempt

In the same page A Remember Me checkbox is provided through which when a user visits the webpage through a certain computer and web browser the website will remember him/her and automatically log him in without the need for authentication. This is only done at the user's will.

In addition, if a user forgets the password of his/her account, by clicking on the "Forgot Your Password?" link the user is navigated through some steps in order to retrieve his/her account. This is done by utilizing the SMTP feature which essentially is an emailing feature. The server is capable of sending an email to the user through which the application confirms his validity and gives him the opportunity to reset his/her password to a new chosen password.

If a new user does not own an account and would like to access the applications, then a registration for an account is required which is done through the Register button. By clicking it the user navigates to the registration form (fig. 23).

By filling the necessary information, a new user account is created and the user now can login. After the registration a verification email is sent to the email address provided by the user in order to verify that it is correct and can be used for the account. The user has to open the email and click in the link that verifies it (fig. 24).

Figure 23: Account Registration in Marine-Electrical

Figure 24: Email sent by Marine-Electrical for User Email verification

Once finally Logged in a dashboard with the available applications appears. On the left side there is a column with a second navigation menu. This menu corresponds to the applications and is only present if a user is logged in. Through this menu the user can navigate to all aspects and pages of the apps. The plus button opens dropdown menus that correspond to the title in the left of the plus button.

In the dashboard A "Logged in as 'User' " message appears which is followed by the current status of email verification.

Finally a Logout button is incorporated in the dashboard and in the dropdown menu corresponding to the Hello User menu item.
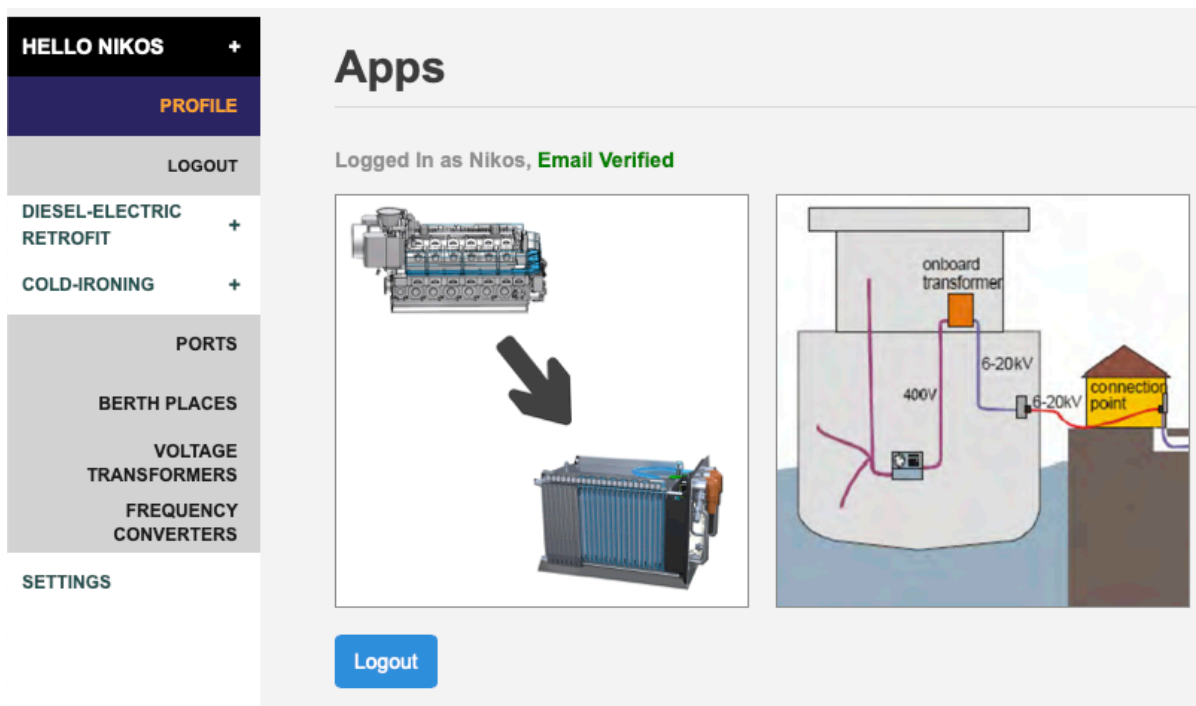
Figure 25: Dashboard of Apps in Marine-Electrical and left column navigation pane (Desktop)

On mobile devices and small screens the navigation menu is retractable to the left side with an arrow responsible for opening and closing. The rest of the page is modified in order to avoid horizontal scrolling. Everything is fitted vertically.
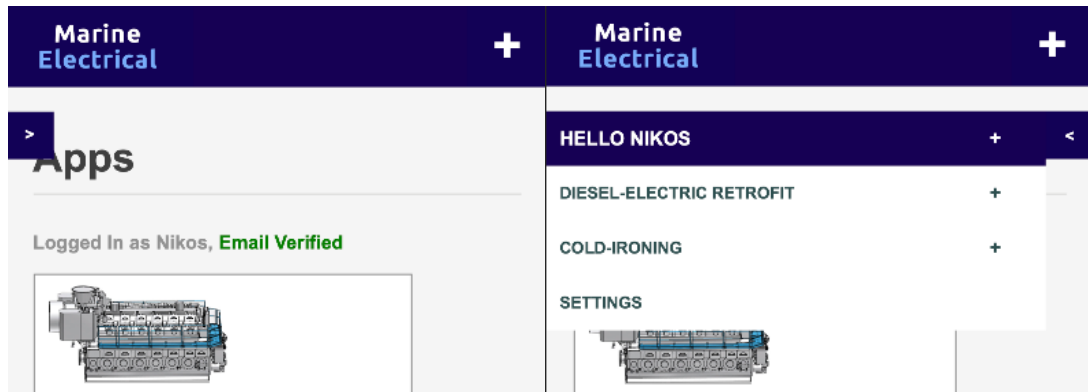
Figure 26: Applications navigation while closed (left) and open (right) (Mobile Screen)

5.4 User Profile

In the Applications navigation pane under the Hello 'User' Title besides the Logout button a Profile button is incorporated through which a page with the User Profile data is presented. The Name, E-mail Address and Password fields can be modified by re-entering them and clicking save. In the case of the password it must be filled twice for confirmation.
Under the Profile tab a Delete button is available if the user wants to permanently delete their account.

Figure 27: User Profile page. Marine-Electrical

5.5 Diesel - Electric Retrofit

5.5.1 Navigation

For the creation of a diesel-electric retrofit, a ship to be retrofitted is needed along with a battery type to be installed as mentioned in chapter 2. In this application these two aspects of a retrofit are inserted separately. This means that the application accommodates unique pages to create, manage and view ships and batteries with their specifications.
These are accessible through the application navigation pane under the Diesel-Electric Retrofit title (by clicking the "+" button, fig. 28).
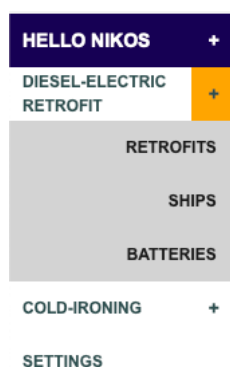
Figure 28: Navigation to the Ships and Batteries of Retrofits. Marine-Electrical

By clicking on either of them a page with a table enlisting all the ships or batteries created along with a summary of their specifications appears (fig. 29). Under the table there is a plus button in order to create a new entry.

Ships

Name	Type	DWT	L	No of M/Es	M/E NCR	No of G/Es	G/E NCR	Delete

+

Ships

Name	Type	DWT	L	No of M/Es	M/E NCR	No of G/Es	G/E NCR	Delete
Marina 1	Aframax Tanker	123123	230	1	25000	4	3500	Delete
Marina 2	Cruise	123123	123	1	123	4	123	Delete
Marina 3	Ferry	45000	105.56	2	402.68	3	30.23	Delete

+

Figure 29: Ships table with and without entries. Marine-electrical

Figure 30: Batteries table with and without entries. Marine-electrical

5.5.2 Ships

Starting with the ships, the creation form include a large amount of information regarding a ship, some of which are not directly needed for the analysis of the retrofit but stand there for adequacy and clarity reason. It consists of 27 fields in 4 categories which are:

1. General
    a. Name
    b. IMO
    c. Class
    d. Flag (Nationalities)
    e. Type
2. Principal Dimensions
    a. Length
    b. Breadth
    c. Depth
    d. Draft
    e. DWT
3. Main Engines
    a. Number of M/Es
    b. M/E MCR
    c. M/E NCR
    d. M/E Manoeuvring Load
    e. M/E NCR Consumption
    f. M/E Manoeuvring Consumption
    g. M/E Efficiency Factor

4. Generator Engines
    a. Number of G/Es
    b. G/E MCR
    c. G/E NCR
    d. G/E Manoeuvring Load
    e. G/E Port Load
    f. G/E NCR Consumption
    g. G/E Manoeuvring Consumption
    h. G/E Port Consumption
    i. G/E Efficiency Factor
    j. DC Voltage

All Loads and operation points are measure in kW, whereas all consumption in gr/kWh. All of the fields in categories 3 and 4 are mandatory in order to provide a satisfactory and complete result. In case any of the data is inserted out of bounds of a possible value or a value is not filled at all, the system warns the user and does not proceed to the creation of a ship or any other object in the application.

All fields are mandatory here and after being fulfilled the Create button is clicked and a new ship is created.

Figure 31: New Ship creation Form (General, Principal Dimensions). Marine-Electrical

Figure 32: New Ship creation Form (Main Engines, Generator Engines). Marine-Electrical

Once the ship is created the user is redirected to the ships page with the addition of their new ship. By clicking on its name a similar tab to the one of the creation page appears including all the data of the ship.

The user there can change any field and click "Save" to update the data of that ship entry (fig. 33).

Figure 33: Editing a ship. Marine-Electrical

Above the tab with the ship data there's also a Delete button in case the ship is no longer wanted by the user (fig. 34).
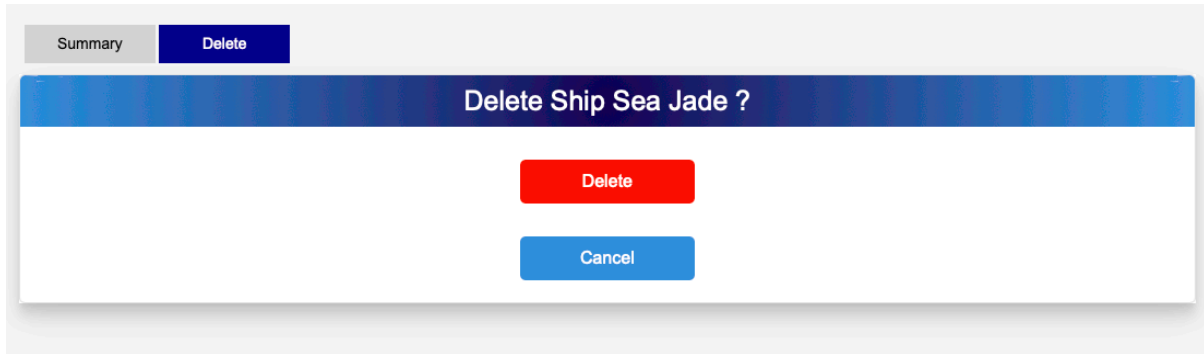
Figure 34: Deleting a ship. Marine-Electrical

5.5.3 Batteries

Exactly the same structure is followed for the batteries. The fields of the battery form are 14 in 3 categories:
1. General Specifications
   a. Maker
   b. Type
   c. V Nominal
   d. Ah
   e. Price
2. Size & Dimensions
   a. Length
   b. Breadth
   c. Height
   d. Weight
3. Operation Details
   a. Charing Current
   b. Current for Max Lifespan
   c. Charging Time for Max Lifespan
   d. Lifespan in cycles
   e. Depth of Discharge

Summary	Delete

Battery "Mitsui A"

General Specifications

Maker: Mitsui

Type: A

V Nominal : 38,4

Ah : 46,2

Price ($/kW) : 1153

Size & Dimensions

Length : 0,306

Breadth : 0,172

Height : 0,172

Weight : 19,6

Operation Details

Charging Current (A) : 23

Curr - Max Lifespan (A): 23

Time - Max Lifespan (h): 2,5

Lifespan (years) : 1000

Depth of Discharge (%): 0,7
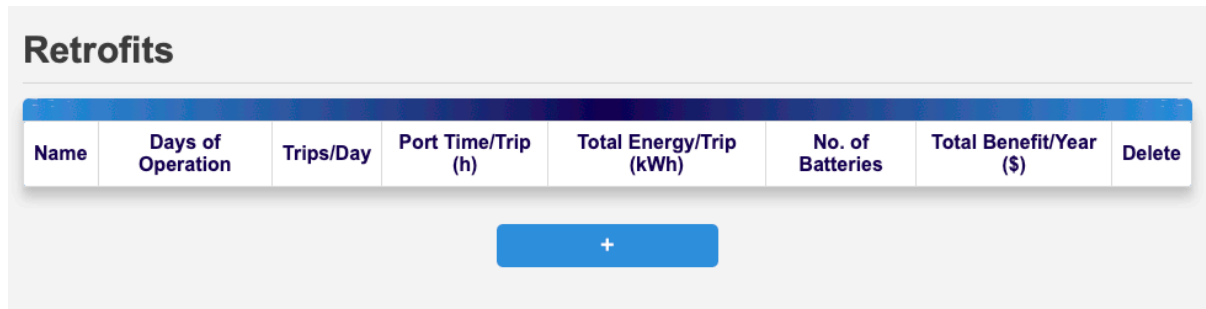
Save

Figure 35: Battery Summary tab. Marine-Electrical
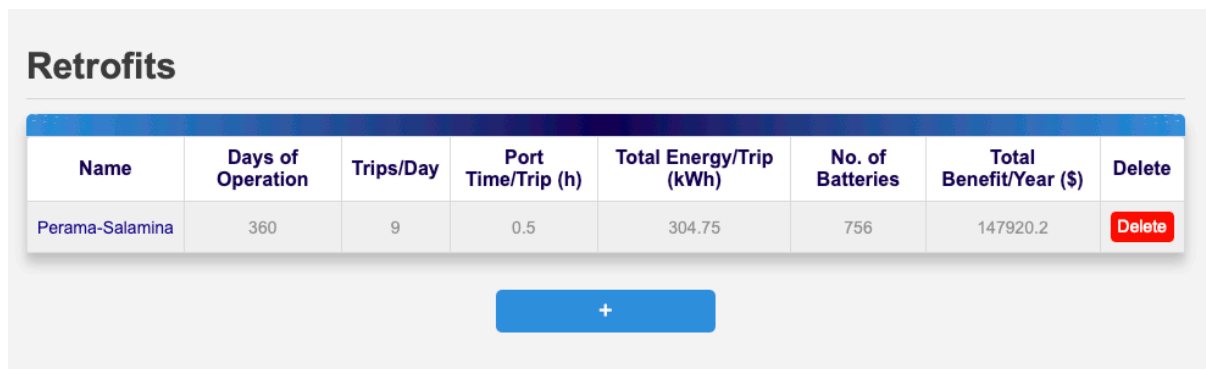
Once all separate input of a diesel-electric retrofit are ready, the user can implement a new retrofit in the same way as a ship or battery.

Figure 36: Empty Retrofits page. Marine-Electrical

Figure 37: Retrofits page with one entry. Marine-Electrical

By navigating to the diesel-electric retrofits page with table and clicking the "+" button a creation form for a retrofit appears whose fields consist of 6 categories and a total of 33 fields:

1. General
   a. Name
   b. Ship, where a list of all created ships is available through dropdown menu (fig. 38)
   c. Battery, where a list of all created batteries is available through a dropdown menu (fig. 39)

Figure 38: Ship selection   Figure 39: Battery selection

2. Type of Calculation. Here 2 choices are available:
   a. With Intermediate Charging, where if selected a field for the time that the ships needs to plug-in/off at port is required
   b. Without Charging, where a number of trips per charge field is required
3. Trips Information
   a. Days of Operation
   b. Trips/day
   c. Port Time[2]
   d. Seagoing Time
   e. Manoeuvring Time
   f. Diversity Factor, from 0 to 1
4. Financial
   a. Initial discount (%)
   b. Inverter
   c. Motordriver
   d. Electric Motor
   e. M/E Sale
   f. G/E Sale
   g. Grant, which if clicked requires the input of a Grant Value in dollars.
5. Operation and Maintenance
   a. Electricity ($/kW)
   b. Fuel ($/Ton)
   c. M/E Maintenance
   d. M/E Shafting Maintenance
   e. G/E Maintenance
   f. Battery Maintenance

---

[2] All Times are measure in hours, financial values in $ and maintenance in $/year

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6. Longterm & Loan.
    a. Longterm checkbox. If checked, 3 fields appear:
        i. Years to Calculate
        ii. Electricity Growing Rate
        iii. Fuel Growing Rate
    b. Loan checkbox (Only checkable if long-term is checked). If checked, 3 fields appear:
        i. Loan Value
        ii. Loan Interest (%)
        iii. Loan Payout Time (Years)

At the bottom of the tab there is a "Save and Calculate" button that leads to the final creation of a retrofit and the process of all calculations.

Figure 40: Portion of the creation form of a retrofit. Marine-Electrical

When clicked the user gets redirected to the table of retrofits with the addition of the new retrofit.
By clicking the retrofit's name a page with 3 tabs appears:
- Summary
- Edit
- Delete

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In the Summary tab the results of all calculations are present as shown in fig. 41 together with a summary of the parameters of the retrofit. The Ship and Batteries are clickable and navigate the user to the corresponding Edit Page of each one of them.
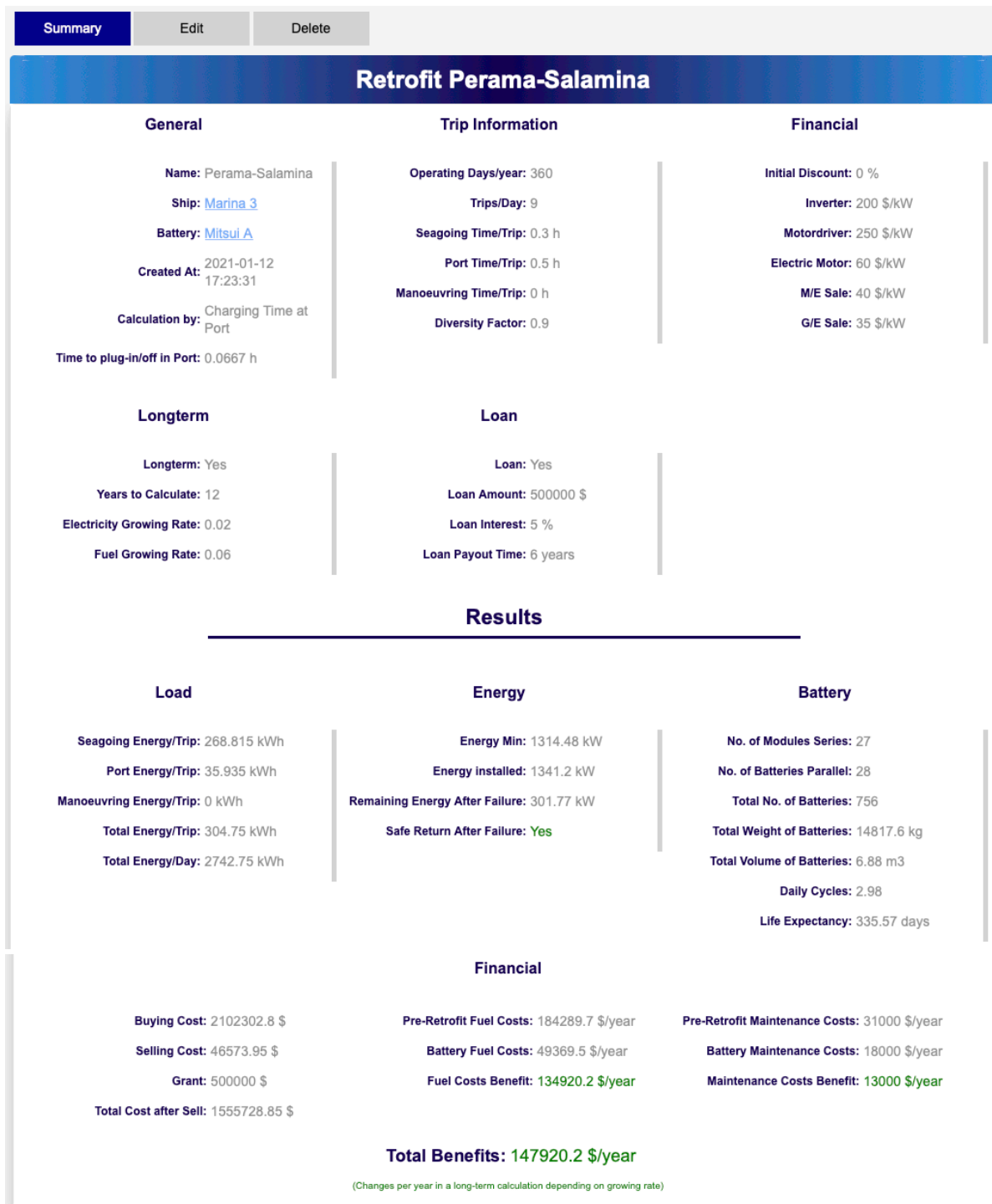
Figure 41: Retrofit Summary with Results. Marine-Electrical

In case the longterm or loan fields are filled then a supplementary financial calculation follows the results along with corresponding charts. The financial calculation table includes the annual benefit, the yearly installment of the loan and the cash flow calculated by adding the annual benefit with the loan installment (negative value obviously). Taking into account the initial cost of the investment a total revenue after each year is calculated by adding to the initial cost the cashflow of each year. Lastly, NPV and IRR indicators are calculated and incorporated in the table. The charts concern the above financial values.

The Edit and Delete tabs work similarly to those of the ships and batteries.
If the ship or battery assigned to the retrofit has been deleted than a warning message appears that informs the user. At the same time the corresponding attribute is set to NULL (fig. 42)

Figure 42: Non-Existent ship of retrofit. Marine-Electrical
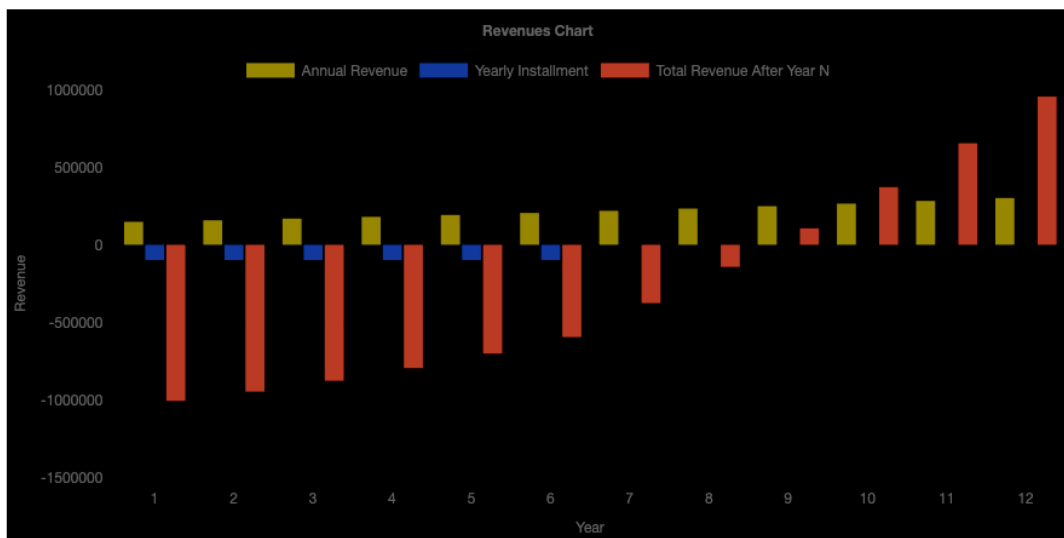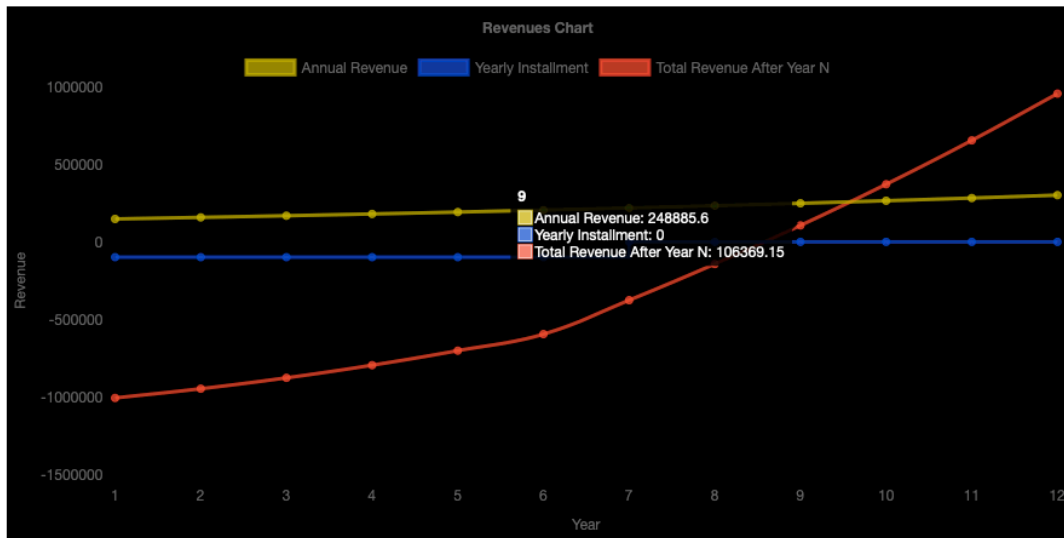
Figure 43: Charts of Fincancial Calculation of a retrofit. Marine-Electrical

Financial Calculation

Years	Initial Cost	1	2	3	4	5	6	7	8	9	10	11	12
Annual Benefit ($)	-1555728.85	147920.2	157990.2	168703.9	180100.7	192222.4	205113.3	218820.4	233393.5	248885.6	265352.5	282853.6	301452.1
Loan / Yearly Installment ($)	500000	-98508.7	-98508.7	-98508.7	-98508.7	-98508.7	-98508.7	0	0	0	0	0	0
Cash Flow of Year N	-1055728.85	49411.5	59481.5	70195.2	81592	93713.7	106604.6	218820.4	233393.5	248885.6	265352.5	282853.6	301452.1
Total Revenue After Year N ($)	-1055728.85	-1006317.35	-946835.85	-876640.65	-795048.65	-701334.95	-594730.35	-375909.95	-142516.45	106369.15	371721.65	654575.25	956027.35
NPV	363669.1 $						IRR				9.7 %		

Figure 44: Table of Financial Calculations of a retrofit. Marine-electrical

5.6 Cold-Ironing

5.6.1 General

In the same way that a user navigates in the Diesel-Electric Retrofit app, he/she can navigate in the Cold-Ironing app. This time there are 2 dependencies, Voltage Transformers, and Frequency Converters, each of which have to implemented before creating a Cold-Ironing project.

For Cold-Ironing, each project is associated with a port. In detail, instead of having a table of cold-ironings there is a table of ports and each port corresponds to a Cold-Ironing project. To this extent, in order to navigate to a project or create a new one the user has to go through the ports page.
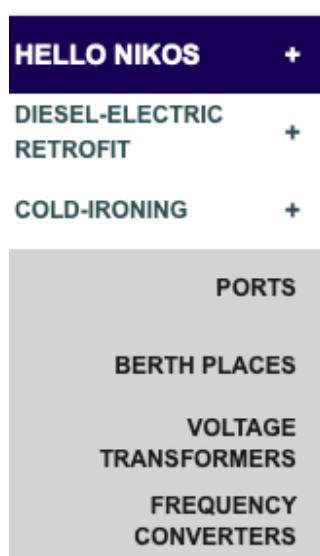
Figure 45: Navigation to the Cold-Ironing application. Marine-Electrical

Before creating a port all of the three abovementioned dependencies are needed. Contrary to the Diesel-Electric retrofit app, here there are some predefined Voltage Transformers and Frequency Converters (see 5.6.2, 5.6.3 and Appendix B). However, if a user prefers to create his own, he is granted that capability.

5.6.2 Voltage Transformers

As mentioned in chapter 2 the installation of Cold-Ironing requires a number of Voltage Transformers depending on the port and number of berth places. All Voltage Transformers registered to a specific user and their data can be accessed through the navigation pane in the Voltage Transformers section (fig. 45).

A table of VTs appears. Here there are some default VTs as well as the user created VTs. The first time of login only the default will appear. New ones can be created by clicking the "+" button (fig. 46).

Voltage Transformers

Maker	Model	Rated Power (kVA)	HV (kV)	Tapping Range (%)	LV (kV)	
ABB	SCR10-315	315	20	0.05	0.4	
ABB	SCR10-400	400	20	0.05	0.4	
ABB	SCR10-500	500	20	0.05	0.4	
ABB	SCR10-630	630	20	0.05	0.4	
ABB	SCR10-800	800	20	0.05	0.4	
ABB	SCR10-1000	1000	20	0.05	0.4	
ABB	SCR10-1250	1250	20	0.05	0.4	
ABB	SCR10-1600	1600	20	0.05	0.4	
ABB	SCR10-2000	2000	20	0.05	0.4	
ABB	SCR10-2500	2500	20	0.05	0.4	
ABB	SCR10-315	315	35	0.05	0.4	
ABB	SCR10-400	400	35	0.05	0.4	
ABB	SCR10-500	500	35	0.05	0.4	
ABB	SCR10-630	630	35	0.05	0.4	
ABB	SCR10-800	800	35	0.05	0.4	
ABB	SCR10-1000	1000	35	0.05	0.4	
ABB	SCR10-1250	1250	35	0.05	0.4	
ABB	SCR10-1600	1600	35	0.05	0.4	
ABB	SCR10-2000	2000	35	0.05	0.4	
ABB	SCR10-2500	2500	35	0.05	0.4	

[+]

Figure 46: Default Voltage Transformers. Marine-Electrical

The default VTs are NOT modifiable or deletable.

A Voltage Transformer creation form consists of 13 fields:

- Maker
- Model
- Rated Power (kVA)
- HV (kV)
- Tapping Range (%)
- LV (kV)
- Connection Symbol
- No Load Loss (W)
- On-Load Loss (W)
- No Load Current (%)
- Short Circuit (Impendance (%)
- Sound Pressure (dB)

- Sound Power (dB)

Every field needs to be filled for adequacy reasons and possible future application additions, however in the actual calculation at the moment of creation only the Rated Power, HV and LV are needed.

Figure 47: Voltage Transformer creation form. Marine-Electrical

5.6.3 Frequency Converters

The Frequency Converters tab almost in identical functionality to the Voltage Transformers, has default entries as well. All adding, deleting and modifying functions are identical to the Voltage Transformers'.

The creation of a Frequency Converter relies on just 4 values:
- Model
- Power Output (kVA)
- Area (m^2)
- Voltage Transformer Area (m^2)

Figure 48: Frequency Converter creation Form. Marine-Electrical

5.6.4 Ports & Berth Places

Similar to the Diesel-Electric retrofit, by clicking on the plus button under the ports table inside the ports page the user gets directed to the port creation form.
In here, all the main attributes for a port regarding a Cold-Ironing installation can be inserted. These are:

1. Port Name
2. The distance between the national grid and the main substation (cable-wise)
3. Cable distances of 20kV cables. These cables correspond to the cables connecting the main substation to the berth places (These fields are required for each type of ship accommodated in the port, separately).
4. Cable distance for 6.6kV and 11kV cables which correspond to the cables that connect the shore-side substation to the connection boxes (These fields are required for each type of ship accommodated in the port, separately).
5. A Voltage Transformer selection
6. Frequency Converters selections with their corresponding amount.

Summary	Edit	Delete

Retrofit Perama-Salamina

General

Name: Perama-Salamina

Ship: Marina 3

Battery: Mitsui A

Created At: 2021-01-12 17:23:31

Calculation by: Charging Time at Port

Time to plug-in/off in Port: 0.0667 h

Trip Information

Operating Days/year: 360

Trips/Day: 9

Seagoing Time/Trip: 0.3 h

Port Time/Trip: 0.5 h

Manoeuvring Time/Trip: 0 h

Diversity Factor: 0.9

Financial

Initial Discount: 0 %

Inverter: 200 $/kW

Motordriver: 250 $/kW

Electric Motor: 60 $/kW

M/E Sale: 40 $/kW

G/E Sale: 35 $/kW

Longterm

Longterm: Yes

Years to Calculate: 12

Electricity Growing Rate: 0.02

Fuel Growing Rate: 0.06

Loan

Loan: Yes

Loan Amount: 500000 $

Loan Interest: 5 %

Loan Payout Time: 6 years

Results

Load

Seagoing Energy/Trip: 268.815 kWh

Port Energy/Trip: 35.935 kWh

Manoeuvring Energy/Trip: 0 kWh

Total Energy/Trip: 304.75 kWh

Total Energy/Day: 2742.75 kWh

Energy

Energy Min: 1314.48 kW

Energy installed: 1341.2 kW

Remaining Energy After Failure: 301.77 kW

Safe Return After Failure: Yes

Battery

No. of Modules Series: 27

No. of Batteries Parallel: 28

Total No. of Batteries: 756

Total Weight of Batteries: 14817.6 kg

Total Volume of Batteries: 6.88 m3

Daily Cycles: 2.98

Life Expectancy: 335.57 days

FC & SST

Voltage Transformer: SCR10-315

Frequency Converters		
PCS 100 SFC-0250	☐	
PCS 100 SFC-0375	☐	
PCS 100 SFC-0500	☐	
PCS 100 SFC-0625	☐	
PCS 100 SFC-0750	☐	

Figure 49: Port creation form for the Cold-Ironing application. Marine-Electrical

At this point, the user has a port which has no berth places. Essentially it is not functioning as it cannot accommodate any ships. In order to make it function berth places have to be added. This can be done in two ways. The first way is through the port's page. When clicking on a listing port that has been created the port's page opens with the usual tabs as in a retrofit (Summary, Edit, Delete) (fig. 50). Except these three, a port has an additional tab called "BPs". This tab contains all the BPs associated with the current port and includes a plus button to add berth places to the port.
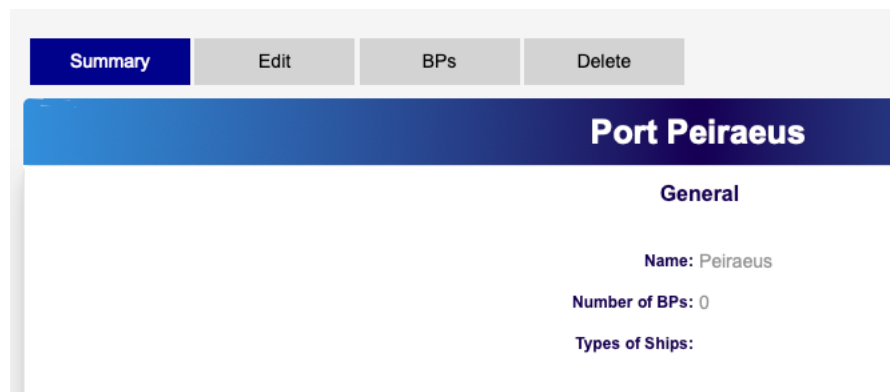
Figure 50: Port Tabs. Marine-Electrical

The second way is through the berth places page, where all berth places of all ports are included (fig. 51). Respectively with the plus button a new berth place can be created.

Figure 51: Berth Places page. Marine- Electrical

In the berth places creation form the below fields exist:
- Port
- Voltage Transformer of the berth place
- The ship type that the berth place accommodates
- The Current Voltage (kV)
- The Frequency that the BP can operate in (Hz)
- The Power Output (kVA)

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Figure 52: Berth Place for the Cold-Ironing application. Marine-Electrical

Once all required berth places have been created the port is fully function and the port page shows a summary of all the details and cost breakdown of the Cold-Ironing Investment.
The cost breakdown includes costs categorized by four categories (Main Substation, Shore-Side Station, Primary Cable Arrangement and Shore-Side Arrangement) (fig. 53).

Figure 53: Port Summary with cost breakdown in a Cold-Ironing investment. Marine-Electrical

Each category contains costs regarding cables, buildings, frequency converters, voltage transformers, double busbars, switchgears, circuit breakers and misc. all referenced in chapter 3 of this dissertation and of course Mr. Diavatis and Mr. Pantazopoulos' dissertations.

Lastly the port page also provides the cost breakdown in a pie chart for enhanced readability (fig. 54).
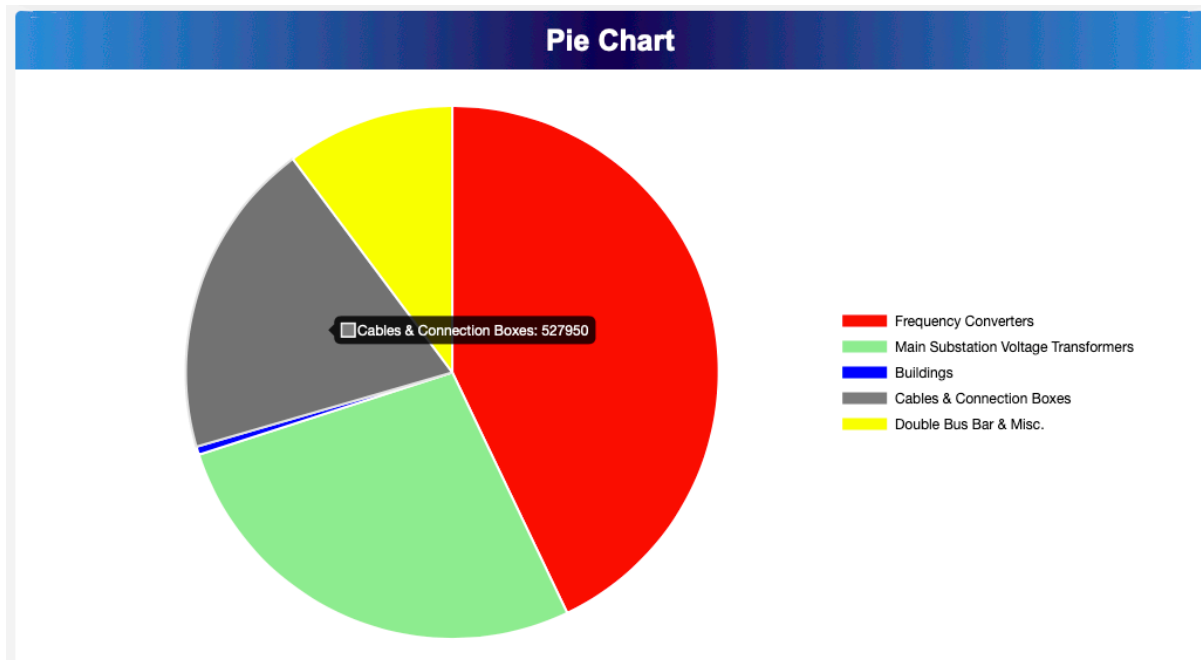
Figure 54: Port Pie Chart (Cost Breakdown). Marine-Electrical

Alike Diesel-Electric retrofit, if any object (e.g. frequency converter) has been deleted that was previously assigned to another object, the user is informed in the corresponding page with a warning that the object is missing and a new one should be assigned.

6. Informational part of Website

6.1 General

In the context of this thesis, the website apart from the web application built also consists of an informational part. This part of the website aims to provide consistent information about the (real life) electrical laboratory (SNAME, NTUA) and its supervisor professor J. M. Prousalidis.

The layout of the website promotes simplicity and readability, with distinct lines and colors separating the divisions of a page. Meanwhile, the navigation aims for clarity with a minimal amount of secondary branches hanging on the main branches. Performance of the website has been of great importance during development while maintaining the possibility of future expansion through templating.

The biggest portion of this part of the website has been built in HTML and CSS. The basic template was designed and built in the early stages of the project as mentioned in chapter 4. It consists of a navigation bar positioned at the top of the page (header), a footer field at the bottom with a summary of the services and communication information and a main body between them. The body also has a right sidebar on occasion, consisted of quick links related to the university, marine engineering and professor J.M. Prousalidis (Currently appears only on the home page, publications and biography pages fig. 55)
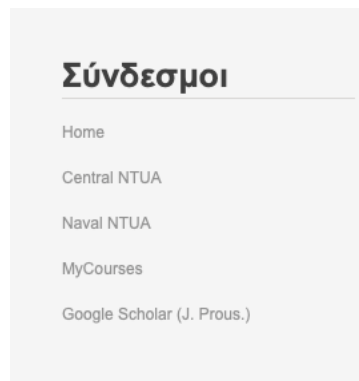
Figure 55: Quick Links in body of Marine-Electrical

The pages included in this part of the website are described in the next paragraphs.

6.2 Home Page

The home page of the web site, also known as the entrance point, features random posts (blog-like), news or general posted information. The main structure of each post consists of an image, text and the post's information (date, publisher, etc.) (fig. 56).

Figure 56: Post on Homepage. Marine-Electrical

6.3 CV – Biography

This page features professor's J. M. Prousalidis Curriculum Vitae in both English and Greek Language. The selection between the two languages is done by a GR|ENG double button at the top-right side of the body. A summary of the biography is presented on the page, whilst a detailed version of the curriculum vitae is available in pdf form through a bottom-right corner button (fig. 57).

Figure 57: Ioannis Prousalidis Biography page. Marine-Electrical

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6.4 Available Classes

All of the courses which Mr. Prousalidis is teaching are presented here. They are categorized in under-graduate, post-graduate and PhD courses. Each lesson has a hoverable image link with its name on it as shown in fig. 58. By clicking on each of them a page with all of its details open up including a summary (fig. 59), the teachers and a link to the corresponding mycourses page (an internet platform of NTUA lessons provided by the Network Center par. 4.4).
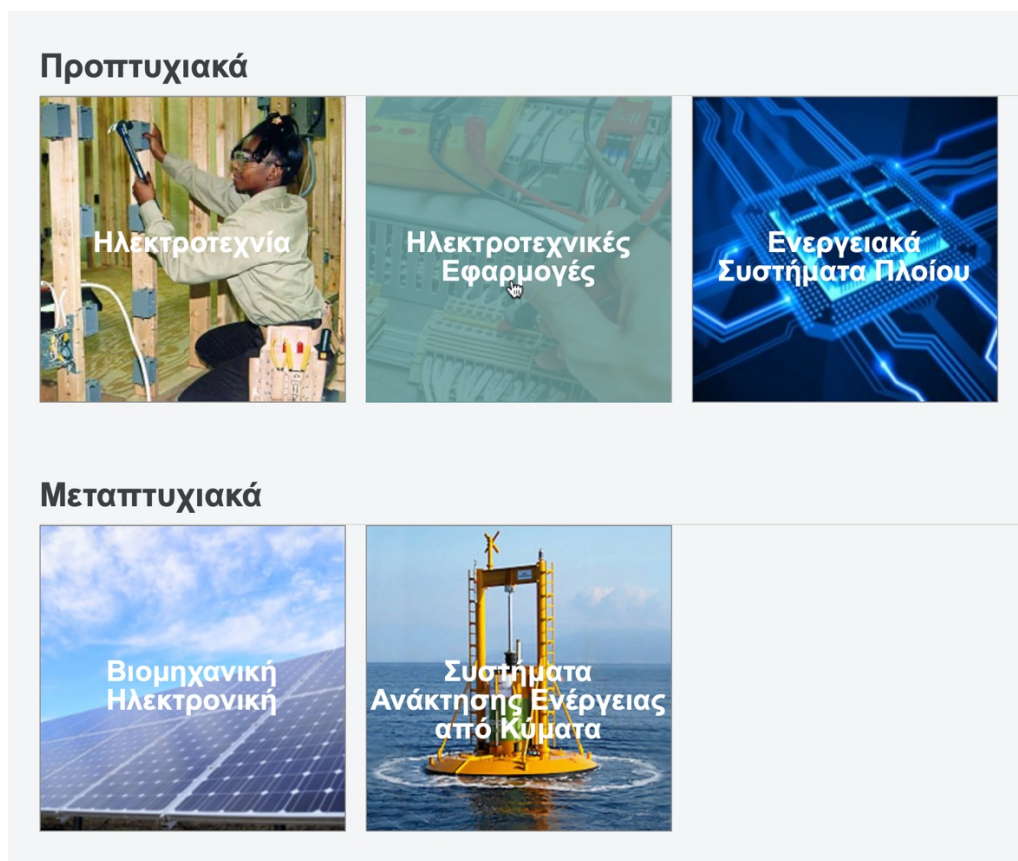

Figure 58: Courses page. Marine-Electrical

Figure 59: Course detailed page. Marine-Electrical

6.5 Publications

Professor J. M. Prousalidis has undertaken a large amount of dissertations which have been published. All of these publications are summarized on this page and enlisted in pdf form as in the CV tab.

6.6 Books

Enlisted on this page all of Mr. Prousalidis books are presented with their ISBN, summary, date, authors and an image of each of them (fig. 60).

Figure 60: Books on Marine-Electrical

6.7 Laboratory (Physical)

The real life electrical laboratory housed in the SNAME and ran mainly by professor J. M. Prousalidis vastly contributes in the teaching process while it hosts a variety of research programs. All of its capabilities and summary are presented in the Laboratory page. The structure of which is similar to an outline leaflet (fig. 61).

3. Εξομοιωτής Ηλεκτρικού Δικτύου Πλοίου

Ο Εξομοιωτής Ηλεκτρικού Δικτύου Πλοίου (Ship Electric Grid Emulator) που σχεδιάστηκε και αναπτύχθηκε στο πλαίσιο του έργου MARINELIVE αποτελεί μικρογραφία ενός τυπικού Συστήματος Ηλεκτρικής Ενέργειας (ΣΗΕ) πλοίου. Το δίκτυο του εξομοιωτή (που απεικονίζεται στο Σχήμα 1, και στις Εικόνες 1-3) διαθέτει τρεις σύγχρονες γεννήτριες (δύο των 5.9 kVA και μία των 5 kVA) , οι οποίες (ή όποιες είναι σε λειτουργία) τροφοδοτούν ένα παθητικό φορτίο RL ή/και ένα τριφασικό κινητήρα επαγωγής, ενώ υπάρχει πρόβλεψη για συνδέσεις άλλων πηγών ηλεκτρικής ενέργειας, είτε απευθείας (για εξομοίωση διασύνδεσης ξηράς και cold-ironing), είτε μέσω διατάξεων ηλεκτρονικών ισχύος (για σύνδεση κυψελών καυσίμου Fuel Cells, όπως η μονάδα NEXA K00-792 του γερμανικού οίκου Heliocentris, βλ. Εικόνα 4 ή άλλων ανανεώσιμων πηγών παραγωγής ηλεκτρικής ενέργειας). Κάθε γεννήτρια έχει ως κινητήρια μηχανή (prime

Σχήμα 1. Διάγραμμα του πειραματικού συστήματος

mover) ένα κινητήρα επαγωγής που οδηγείται από ένα μετατροπέα ηλεκτρονικών ισχύος, ο οποίος με τη σειρά του τροφοδοτείται από τον πίνακα του εργαστηρίου. Σημειώνεται ότι, καθώς

Figure 61: Physical Laboratory page. Marine-Electrical
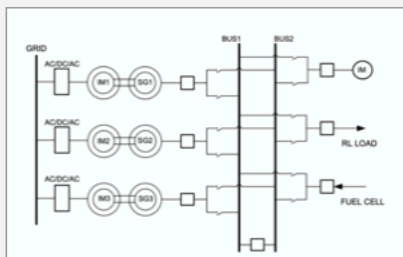
6.8 Research Actions & Programs

Lastly a page dedicated to all of the research done by the electrical lab and professor Prousalidis is under the Research Actions & Programs tab. The page consists of a list of all actions and programs in separated in two divisions respectively (fig. 62).

Ερευνητικές Δράσεις Και Προγράμματα

Ερευνητική Δραστηριότητα

1992-1993:	συμμετοχή σε Ομάδα Εργασίας του ΤΕΕ με θέμα: "Μελέτη Αναπτυσσομένων Υπερτάσεων σε Υπόγειους Μεταλλικούς Αγωγούς Φυσικού Αερίου".
1990-σήμερα:	Εξομοίωση (μοντελοποίηση) στοιχείων Συστημάτων Ηλεκτρικής Ενέργειας όπως μετασχηματιστές, γραμμές μεταφοράς, ηλεκτρόδια γείωσης, διακόπτες ισχύος, απαγωγείς υπερτάσεων, ηλεκτρονικά ισχύος κ.λπ. για προσομοίωση ταχέων ηλεκτρομαγνητικών φαινομένων μέσω εξειδικευμένων υπολογιστικών προγραμμάτων, όπως EMTP/ATP, PSCAD, MATLAB/PSB κ.λπ.
2001-σήμερα:	Ανάλυση και μελέτη συστημάτων ηλεκτρικής ενέργειας πλοίου με ιδιαίτερη βαρύτητα στο σχεδιασμό συστημάτων ηλεκτρικής πρόωσης όπως και σε θέματα ποιότητας ηλεκτρικής ενέργειας τέτοιων εγκαταστάσεων.

Ερευνητικά Προγράμματα

1. "Προγράμματα Η/Υ για την Αποκατάσταση Συστήματος Ηλεκτρικής Ενέργειας μετά από Γενική Διακοπή Ισχύος" (χρηματοδότης: ΓΓΕΤ – ΔΕΗ, επιστημονικός υπεύθυνος: καθηγητής Β. Παπαδιάς).
2. "Lightning Protection of Wind Turbines" (χρηματοδότης: ΕΟΚ, πρόγραμμα JOULE, επιστημονικός υπεύθυνος: καθηγητής Ν. Χατζηαργυρίου).
3. "Βελτίωση Ποιότητας Μετασχηματιστών Διανομής" (χρηματοδότης: ΓΓΕΤ - όμιλος Schneider Greece, πρόγραμμα ΥΠΕΡ, επιστημονικός υπεύθυνος: καθηγητής Ν. Χατζηαργυρίου).
4. "Αξιολόγηση και Αναμόρφωση του Προγράμματος Προπτυχιακών Σπουδών του Τμήματος ΗΜ&ΜΥ ΕΜΠ" (χρηματοδότης:ΥΠΕΠΘ-Ε.Ε., πρόγραμμα ΕΠΑΕΑΚ- Ι, επιστημονικός υπεύθυνος: καθηγητής Γ. Κονταξής)

Figure 62: Research Actions & Programs page. Marine-Electrical

7. Deployment

7.1 Problems faced

Throughout the whole procedure, as in every development project, numerous bugs and problems were faced and needed solution.

Some of the main problems faced regarded the display of the two navigation panes of the website on both a desktop and a mobile screen. The transition between the two displays and the differentiation in implementation of the two designs comprised of a time consuming matter that was dealt with.

An even bigger issue emerged when creating the user authentication feature. After the user registers a verification e-mail is supposed to be sent and the link inside it to automatically log in the user and verify their e-mail. This process presented bugs and issues one of which was that it did not recognize the user authentication thus not logging in or verifying the e-mail correctly. A more complex approach to the matter was needed (explanation is out of scope of this thesis) in order to solve them which occupied a considerable amount of time.

Another problem initially faced which posed a huge risk for the whole project was that of the available space provided by the NTUA Network Center. The available space was limited to 100 MB which at that time was almost half the size of the project created without yet having all the media files in it. A special procedure of deleting unnecessary modules had to take place in order to find the space needed, however there was a risk of hitting the limit with the rest of the media. Fortunately, the project was narrowed by cutting size from every possible aspect and fitted in the 100 MB space.

Concerning bugs of the calculation algorithms on runtime, an instance happened in the calculation of the IRR attribute. When a calculation of very low NPV occurred with close to zero, or negative yearly cashflow, the IRR was almost zero. The calculation of the IRR is the product of a loop recalculating the IRR until it fits the given NPV. This calculation in such occurrences took so long as to timeout the request (surpassing the 30 second limit of an http request). In such situations a certain measure was taken in order to end the calculation before the timeout limit without losing accuracy in the result.

7.2 Procedure of Deployment

When all of the website aspects and attributes were deemed ready to operate after tries in the local server (MAMP, see chapter 4) a procedure took place in order to deploy the website under the actual server of Marine-Electrical.
The Network Center provided the space with all of its features under the address: marine-electrical.naval.ntua.gr.

The first step towards deploying was to change all the settings of the project in order to fit the server and the "live" status. Such settings were:

- The addresses referenced (changed from localhost to marine-electrical.naval.ntua.gr)
- The structure of the files and folders as to fit the structure required by the server in order to operate. This means that the index file, which is the first file accessed when a client request is made, should be placed along with all of the subfolders and files, in the right places to avoid any file access error.
- The database name, username and password in the project files in order to gain access to the database
- The SMTP server address, name and password, to operate the emailing feature.
- The DEBUG setting, which should change from true to false for the purpose of not showing debug information to a client when a website error occurs, consequently avoiding security holes.

The second step was to upload all the files and folders to the server. This was done by utilizing an FTP client, FileZilla.

FTP stand for File Transfer Protocol and is a standard networkd protocol used for the transfer of computer files between a client and a server on a computer network.

FileZilla is a free software, cross-platform FTP application, consisting of FileZilla Client and FileZilla Server (7). It allows the user to make an ftp connection in a graphical environment with the intention of transferring files from/to a server.

Once the uploading was complete the databases had to be migrated from the local server to the marine-electrical server. This was done with a simple SQL export from one server and an SQL import to the other. However the databases used in the two places were not identical leading to a problem.

The database on the server had a limitation on some database variables regarding their size which had to be smaller than the created ones on the local server. Despite the fact the size of the variables allowed on the server was enough for the application to operate perfectly, so with just the appropriate alterations the database was migrated without any errors.

For a certain period after deploying the website an under construction page was set up and the website was not accessible. This was done in order to provide a time frame for debugging on the live website and in conciliation with Mr. Prousalidis to make changes to anything needed.

8. Conclusion & Recommendations

8.1 Conclusion

Web technology has reached a point where it can provide its users with great capabilities even for universities. It has opened the road to universal tools available all over the world. Such a tool has been built for the marine engineering electrical lab of the NTUA with immediate application at the same time with an information site of the physical lab and Mr. Prousalidis.

Concerning the tools, the two applications developed, diesel-electric retrofit analysis and cold-ironing analysis applications currently concern fields of marine engineering with great interest under the spectrum of a more environmentally friendly means of transport as well as a more financially efficient wat of producing energy both in seagoing and port situations. The evolution of these fields is increasing day by day and tools such as the marine-electrical applications could become very important.

8.2 Recommendations

The applications built provide a great start for a large set of different tools accommodated in a digital laboratory so further development of more tools like these are encouraged. The design and environment could be also further developed in the interest of user friendliness.

8.2.1 Diesel-Electric Retrofit

At the same time, regarding the diesel-electric retrofit:
- A set of standard batteries could be created from which a user could select instead of inserting the fields on their own.
- In addition, a feature could be added where the user gets recommendation of batteries and final results by calculations of the current engines output.
- Finally an analysis of the space available on a ship could be done with the purpose of providing information on whether a certain battery can be fitted.

8.2.2 Cold-Ironing

Concerning the Cold-Ironing application:
- An analysis of a port's traffic could be featured through inserting information for the port which would lead in a financial calculation of the amortization of an investment
- A population of the types of ships, voltage transformers and frequency converters with more preset options

Reference

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2. **Diavatis, Ioannis.** *Development of an application in computational environment for the techno-economic feasibility analysis of the shore-to-ship power connection (SSP - Cold Ironing).* **2019.**

3. **DNV-GL.** *DNV-GL.* **[Online] https://www.dnvgl.com/news/sulphur-limit-in-ecas-increased-risk-of-psc-deficiencies-and-detentions-142911.**

4. **ABB.** *ABB.* **[Online] https://new.abb.com/.**

5. **Google Images.** *Google Images.* **[Online] www.google.com.**

6. **Pantazopoulos, Dionysios.** *Διερεύνηση της Ηλεκτρικής Διασύνδεσης Πλοίων στα Λιμάνια του Πειραιά και της Κυλλήνης.* **2019.**

7. **Wikipedia. [Online] www.wikipedia.org.**

8. **Hot Frameworks.** *Hot Frameworks.* **[Online] https://hotframeworks.com.**

9. **Statista.** *Statista.* **[Online] https://www.statista.com/.**

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12. **Michail, Dimitrios.** *Development of a computational environment for the technical and financial assessment of vessels with hybrid-electric propulsion.* **2019.**

13. **Bakirtzoglou, Christos.** *Techno-economical feasibility study on the retrofit of double-ended Ro/Pax ferries into battery-powered ones .* **2017.**

Appendix. Voltage Transformers and Frequency Converters

A.1 Voltage Transformers

Maker	Model	Rated Power (kVA)	HV (kV)	Tapping Range (%)	LV (kV)
ABB	SCR10-315	315	20	0.05	0.4
ABB	SCR10-400	400	20	0.05	0.4
ABB	SCR10-500	500	20	0.05	0.4
ABB	SCR10-630	630	20	0.05	0.4
ABB	SCR10-800	800	20	0.05	0.4
ABB	SCR10-1000	1000	20	0.05	0.4
ABB	SCR10-1250	1250	20	0.05	0.4
ABB	SCR10-1600	1600	20	0.05	0.4
ABB	SCR10-2000	2000	20	0.05	0.4
ABB	SCR10-2500	2500	20	0.05	0.4
ABB	SCR10-315	315	35	0.05	0.4
ABB	SCR10-400	400	35	0.05	0.4
ABB	SCR10-500	500	35	0.05	0.4
ABB	SCR10-630	630	35	0.05	0.4
ABB	SCR10-800	800	35	0.05	0.4

ABB	SCR10-1000	1000	35	0.05	0.4
ABB	SCR10-1250	1250	35	0.05	0.4
ABB	SCR10-1600	1600	35	0.05	0.4
ABB	SCR10-2000	2000	35	0.05	0.4
ABB	SCR10-2500	2500	35	0.05	0.4

Table 3: Preset Voltage Transformers

A.2 Frequency Converters

Model	Power Output (kVA)	Area (m2)	Voltage Transformer Area (m2)
PCS 100 SFC-0250	250	0.64	0.64
PCS 100 SFC-0375	375	0.64	0.96
PCS 100 SFC-0500	500	0.64	0.96
PCS 100 SFC-0625	625	1.28	0.96
PCS 100 SFC-0750	750	1.6	0.96
PCS 100 SFC-0875	875	1.92	3.68
PCS 100 SFC-1000	1000	1.92	3.68
PCS 100 SFC-1125	1125	1.92	3.68
PCS 100 SFC-1250	1250	3.52	3.68
PCS 100 SFC-1375	1375	3.52	3.68
PCS 100 SFC-1500	1500	3.52	3.68
PCS 100 SFC-1625	1625	3.52	3.68
PCS 100 SFC-1750	1750	4.16	3.68
PCS 100 SFC-1875	1875	4.16	3.68
PCS 100 SFC-2000	2000	4.16	3.68
PCS 6000 SFC-4000	4000	5.88	0

PCS 6000 SFC-5000	5000	5.88	0
PCS 6000 SFC-6000	6000	5.88	0
PCS 6000 SFC-7000	7000	5.88	0

Table 4: Preset Frequency Converters