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Programme Stratégie énergétique 2050 des transports publics (SETP 2050)

SNL Fleet Electrification 2020-2035

MN Ceresio and Ground Station Project (Project 230)

Final Report

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Lugano, il 25.08.2025

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Summaries

Summary in English

Project Venti35 was launched by Società Navigazione del Lago di Lugano (SNL) with the aim of retrofitting its current fleet of boats on Lake Lugano with electric motors. This will result in the entire fleet being emission-free, leading to a total approximate savings of 16’858 tons of CO_2 by 2035. This estimation is based on the electrification roadmap of the SNL fleet considering that the average diesel consumption, and following CO_2 emission, of each electrified vessel become zero from the year of its electrification. This project, together with SNL's ongoing activities in the field of strategic mobility, aims to significantly contribute to our vision of sustainable navigation, not solely for Lake Lugano, but all of Switzerland. Through this project SNL strives to set a positive example for all other navigation companies operating on Swiss lakes. CO_2 emissions are one of the principal causes of global warming, and the aim of the Swiss Confederation is to eliminate these emissions by 2050. To contribute towards this important goal, SNL has already taken the first steps of Project Venti35 with the project outlined in this report, with the retrofitting of the diesel-powered MN Ceresio to an electric engine and implementing all the required charging infrastructure.

The project presented here outlines the two primary steps in SNL’s larger overarching project: retrofitting of the MN Ceresio, a ship originally built in 1931, with an electric motor, and installing the charging infrastructure required for its operation. This report outlines the planning, operation, and testing phases of this project, as well as technical specifications for the required engines and infrastructure. The reasoning and rationale behind major decisions regarding the projects’ outcome are discussed, with a focus on how this experience can be used moving forward with Project Venti35. The project has resulted in an incredible success, and SNL is proud to have provided a glowing example to other navigation companies in Switzerland with interest in following in its footsteps towards a future of sustainable navigation.

Zusammenfassung auf Deutsch

Die Schifffahrtsgesellschaft des Luganer Sees – SNL (Società Navigazione del Lago di Lugano) hat das Projekt Venti35ins Leben gerufen, um die bestehende Diesel-Schiffsflotte auf dem Ceresio auf Elektromotoren umzurüsten. Durch diese Maßnahme wird die gesamte Flotte emissionsfrei, was bis 2035 zu einer Gesamteinsparung von rund 16.858 Tonnen CO_2 führen wird. Diese Schätzung basiert auf der Elektrifizierungs-Roadmap der SNL-Flotte, die davon ausgeht, dass der durchschnittliche Dieselverbrauch und die damit verbundenen CO_2-Emissionen jedes elektrifizierten Schiffes ab dem Jahr der Umrüstung auf NULL sinken

werden.

Das Projekt soll – zusammen mit den laufenden Aktivitäten der SNL im Bereich der strategischen Mobilität – einen wichtigen Beitrag zur Vision einer nachhaltigen Schifffahrt leisten, nicht nur auf dem Luganer See, sondern in der ganzen Schweiz. Zudem möchte die SNL mit diesem Projekt ein positives Beispiel für alle anderen Schifffahrtsunternehmen auf den Schweizer Seen setzen.

CO_2-Emissionen gehören zu den Hauptursachen der globalen Erwärmung, und das Ziel der Schweizerischen Eidgenossenschaft ist es, diese Emissionen bis 2050 zu eliminieren. Um zu diesem wichtigen Ziel beizutragen, hat die SNL im ersten Schritt des Projekts Venti35 das bisher dieselbetriebene MS Ceresio auf einen Elektromotor umgerüstet und gleichzeitig die erforderliche Ladeinfrastruktur geschaffen. Dieses Teilprojekt umfasst zwei wesentliche Maßnahmen innerhalb des übergeordneten SNL-Projekts: die Umrüstung eines alten (in diesem Fall 1931 gebauten) Schiffes auf einen elektrischen Antrieb sowie die Installation der für den Betrieb notwendigen Ladeinfrastruktur.

In dem zugehörigen Bericht werden die Planungs-, Betriebs- und Testphasen des Projekts sowie die technischen Spezifikationen der benötigten Motoren und Infrastruktur beschrieben. Zudem werden Überlegungen und Entscheidungsgründe im Hinblick auf das Projektergebnis erörtert, wobei der Fokus darauf liegt, wie diese Erfahrungen für das Gesamtprojekt Venti35 genutzt werden können.

Venti35 ist ein außergewöhnlicher Erfolg, und die SNL ist stolz darauf, anderen Schifffahrtsunternehmen in der Schweiz, die ihrem Beispiel folgen möchten, als Vorbild für eine nachhaltige Schifffahrt der Zukunft zu dienen.

Riassunto in italiano

Il Progetto Venti35 è stato lanciato dalla Società Navigazione del Lago di Lugano (SNL) con l'obiettivo di realizzare una navigazione sostenibile a zero emissioni, convertendo sua attuale flotta di imbarcazioni con motori elettrici ed introducendo nuovi natanti innovativi e sostenibili.
L’elettrificazione della flotta attuale sul lago di Lugano, entro il 2035, porterà un risparmio totale stimato di 16.858 tonnellate di CO2 nel periodo di progetto. Questa stima si basa sulla roadmap di elettrificazione della flotta SNL, considerando che il consumo medio di diesel e, di conseguenza, le emissioni di CO2 di ciascuna imbarcazione elettrificata diventeranno pari a zero a partire dall'anno della loro conversione.
Questo progetto, insieme alle attività strategiche di mobilità già in corso presso SNL, mira a contribuire in modo significativo alla nostra visione di navigazione sostenibile, non solo per il Lago di Lugano, ma per tutta la Svizzera.

Con il Progetto Venti35, SNL intende offrire un esempio positivo per tutte le altre compagnie di navigazione operanti sui laghi svizzeri. Le emissioni di CO2 sono una delle principali cause del riscaldamento globale e l'obiettivo della Confederazione Svizzera è di eliminarle entro il 2050.
Per contribuire a questo ambizioso traguardo, SNL ha già avviato i primi passi del progetto con la riconversione della motonave MN Ceresio, precedentemente alimentata a diesel, con un motore elettrico e con l'implementazione di tutta l'infrastruttura di ricarica necessaria.
Il progetto presentato in questo rapporto descrive le due fasi principali di questa iniziativa: La conversione della MN Ceresio, una nave costruita originariamente nel 1931, con un motore elettrico, e l'installazione dell’infrastruttura di ricarica necessaria.
Il rapporto illustra le fasi di pianificazione, operatività e test del progetto, nonché le specifiche tecniche dei motori e delle infrastrutture richieste. Inoltre, vengono analizzate le motivazioni e le logiche dietro le principali decisioni prese, con un focus su come questa esperienza possa essere utilizzata per i futuri sviluppi del Progetto Venti35.
Il progetto ha ottenuto un successo straordinario e SNL è orgogliosa di aver fornito un esempio virtuoso per le altre compagnie di navigazione in Svizzera interessate a intraprendere la stessa direzione verso un futuro di navigazione sostenibile.

1 Initial situation

SNL, a renowned Swiss company, boasts a diverse fleet of vessels catering to a range of passenger capacities spanning from 30 to 600. Operating tirelessly 365 days a year, SNL is a stalwart presence on the waters of Ticino, offering essential public transportation services on Lake Maggiore, as well as scenic tourist excursions on Lake Lugano. The heart of SNL's operations lies at its shipyard, nestled along the lake in Cassarate, a suburb of Lugano, where its impressive fleet of 11 vessels is moored. Powered by diesel engines, these vessels collectively consume approximately 260,000 litres of diesel fuel annually. As a result of this, SNL harbours a forward-thinking vision to usher in an era of sustainability by transitioning its fleet to achieve zero-emission status by 2035.

1.1 Charging stations

The journey toward this ambitious goal commenced with a pioneering step: the electrical retrofitting of the MN Vedetta, a modest 30-seat vessel, which was successfully completed in 2016. Buoyed by this initial success, SNL embarked on the retrofitting process for larger vessels, beginning with the MN Ceresio. The selection of the MN Ceresio was deliberate, guided by several key factors including its optimal hull shape, modest diesel engine output (a mere 168 kW), ample space for battery storage, and minimal onboard amenities translating to lower power consumption. Concurrently, SNL faced the intricate task of strategically locating charging stations, mindful of each station's capabilities and operational constraints. Effective communication with the local energy supplier, Aziende Industriali di Lugano (AIL) was paramount during the project's nascent stages. Collaboratively, SNL and AIL identified suitable locations for charging stations, considering technical feasibility and potential limitations. One such instance underscored the importance of this collaboration: the initial plan to equip the main pier in the heart of Lugano with a 4 MW charging capacity was reassessed following discussions. Recognizing spatial constraints, AIL advised for a downscaled 2 MW charging capacity station to be installed. While this adjustment posed potential operational challenges for SNL, meticulous brainstorming sessions and a comprehensive analysis of battery dimensions versus charging time and duration (Figure 1) allowed SNL to adapt effectively. Ultimately, SNL determined that the revised power output sufficed to meet AIL's requirements without compromising operational efficiency. The following table outlines the calculations used to provide us with an estimate of the required battery capacity for the remaining boats in our fleet. We used the MNE Ceresio as a baseline, and compared the power usage, capacity and physical dimensions of each boat to calculate a weighted coefficient.

							40%	30%	10%	20%	
	KW	Pax	Year	Weight (Tons)	Length (m)	Width (m)	Effective KW	Effective Pax	Effective weight	Effective dimensions	Coefficient
MNE Vedetta 1908	29	30	1908	2.3	11.4	2.7	17.9%	12.5%	12.8%	15.6%	15.3%
MNE Ceresio 1931	162	240	1931	18.0	31.4	6.3	100.0%	100.0%	100.0%	100.0%	100.0%
MN Lugano 1961	490	600	1961	22.5	47.1	9.1	302.5%	250.0%	125.0%	217.7%	252.0%
MN Italia 1962	441	600	1962	22.5	47.1	9.1	272.2%	250.0%	125.0%	217.7%	239.9%
MN Gottardo 2001	529	300	2001	22.5	41.8	7.8	326.5%	125.0%	125.0%	165.6%	213.7%
MN Paradiso 1978	131	220	1978	16.5	28.3	6.0	80.9%	91.7%	91.7%	86.1%	86.2%
MN Morcote 1977	178	220	1977	16.5	28.3	6.0	109.9%	91.7%	91.7%	86.1%	97.8%
MN Milano 1927	203	150	1927	11.3	32.0	6.6	125.3%	62.5%	62.8%	107.3%	96.6%
MN S.Lorenzo 1987	169	60	1987	4.5	17.2	4.4	104.3%	25.0%	25.0%	38.0%	59.3%
MN S.Ambrogio 1988	169	60	1988	4.5	18.0	4.3	104.3%	25.0%	25.0%	39.3%	59.6%

Figure 1 - Analysis of estimated battery requirements for each ship

Figure 2 shows the different charging station on Lake Lugano in 2024. The Red Circle shows the “Fast Charge” station, while the yellow circle shows the “slow charge” station. The idea moving forward is to develop an additional charging station at the new pier of Melide’s train station upon its completion (Figure 3).

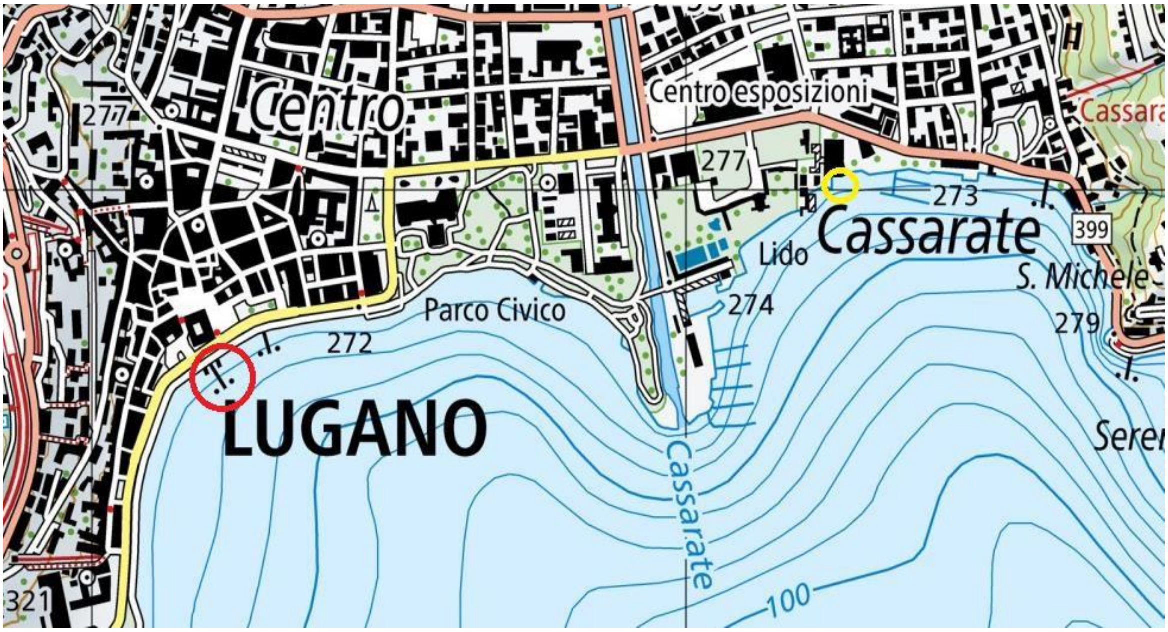

Figure 2 - Location of boat charging stations on Lake Lugano (2024)

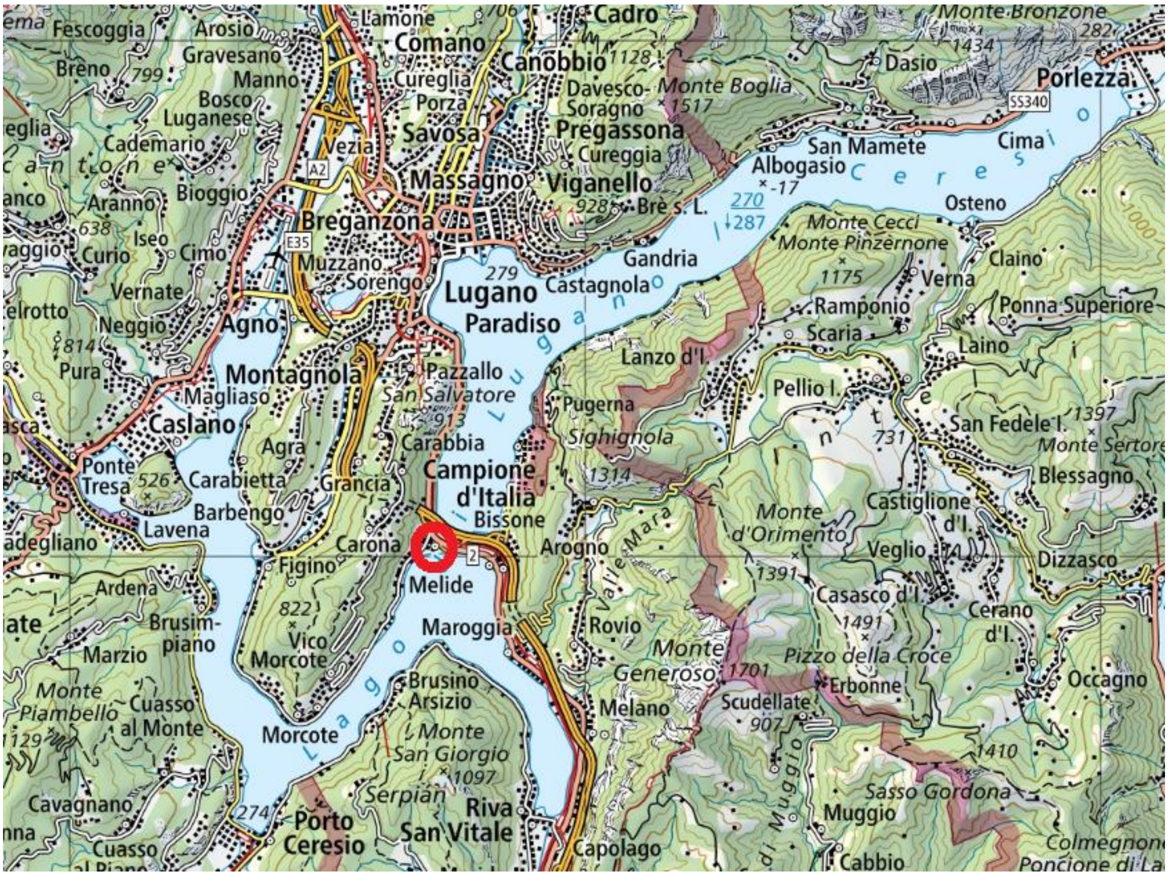

Figure 3 - Planned location of future charging point.

1.2 Vessel requirements

To evaluate the power required for the MN Ceresio, we calculated the power needed to navigate from the SNL Shipyard - Lugano Centrale - Porto Ceresio and back, 3 times. Porto Ceresio is located on the far, South-west shore of Lake Lugano (visible in Figure 3), so this measurement considers the longest route SNL will need to navigate, therefore representing the worst-case scenario for power requirements.

Several assumptions needed to be made for these initial calculations, so the following is what was considered. The marine propulsion system is a purely electric propulsion system, with the energy supply provided by the battery. The torque generated by the electric motor is transmitted directly to the ship's propeller via the drive shaft, and the propulsion power provided by a double-wound propulsion motor. The scope of development focused was based on requirements of the Swiss Ufficio Federale dei Trasporti (UFT) and European Standard for Technical Requirements for Inland Navigation (ES-TRIN). This means that the technical design as well as safety-relevant aspects of the overall system were designed to meet the requirements of the licensing organizations. The aim was to develop a modern, future-proof e-ship approved by the UFT. For SNL, an intuitive, visually appealing, and operationally safe Human Machine Interface (HMI) for the control panel had to be considered. Future security included maintaining sufficient performance reserves for future system expansions (software and/or hardware).

Having made these calculations (Figure 4) SNL evaluated if the power available from available electrical propulsion systems was enough to meet our requirements to power the vessel. In addition to this power requirement, an extra 1/3rd of this capacity needs to be added as an emergency reserve, and an additional 1/3rd to provide increased power in unusual cases (e.g. strong winds, large waves, power supply issues, etc.) to ensure there is always enough power available for the vessel. Therefore, the minimum required battery capacity is calculated by adding an additional 2/3^{rds} of the theoretical requirement. Taking the example in Figure 4, the theoretical power requirement is 438 kWh, so an additional 291 kWh (66.6% of 438) is added, giving a total minimum battery capacity of 728 kWh. (Figure 5, Option 1). Note that as there is no need to load new passengers after step 9 of this example a smaller waiting period has been added to the calculations. Option 1 is related to a smaller boat, such as the MNE Ceresio, while Options 2 and 3 are estimates for larger boats in our fleet.

Step	Description	Distance (km)	Average Power needed by propeller motor (kW)	Power required by ship's onboard system (kW)	Converter Power Loss (kW)	Total Power Draw (kW)	Average ship speed (km/h)	Transit Time (h) / Waiting time (h)	Transit Time (min.) / Waiting time (min.)	Energy required from Battery (Kwh)- Power draw for a determined time
1	Shipyard to Lugano Centrale	1.92	60	5	3	68	12	0.16	9:36	10.88
2	Waiting at Lugano	0	0	5	0	5	0	0.15	9:00	0.75
3	Lugano to Porto Ceresio	12.92	160	7	5	172	21.5	0.60	36:03	103.36
4	Waiting at Porto Ceresio	0	0	5	0	5	0	0.15	9:00	0.75
5	Porto Ceresio to Lugano	12.92	160	7	5	172	21.5	0.60	36:03	103.36
6	Waiting at Lugano	0	0	5	0	5	0	0.15	9:00	0.75
7	Lugano to Porto Ceresio	12.92	160	7	5	172	21.5	0.60	36:03	103.36
8	Waiting at Porto Ceresio	0	0	5	0	5	0	0.15	9:00	0.75
9	Porto Ceresio to Lugano	12.92	160	7	5	172	21.5	0.60	36:03	103.36
10	Waiting at Lugano	0	0	3	0	2.5	0	0.08	5:00	0.21
11	Lugano to Shipyard	1.92	60	5	3	68	12	0.16	9:36	10.88
Total	Steps 1-11	-	-	-	-	-	-	-		438.41

Figure 4 - Calculations for battery usage for the Lugano - Porto Ceresio route

	Option 1	Option 2	Option 3
Rated power of electric motor (kW)	162.0	400.0	900.0
Velocity (km/h)	21.5	24.0	28.0
Duration of navigation Lugano - Porto Ceresio (h)	0.60	0.54	0.46
Duration of navigation (minutes)	36'.00"	32'.18"	27'.41"
Battery power required for navigation (kW)	172	417	927
Energy required for steps 1-11 (kWh)	438	926	1'731
Minimum required battery capacity (kWh), considering the usage between 20% and 80%	730	1'543	2'885
Number of 122 kWh batteries	6	13	24
Effective battery capacity (kWh)	732	1'586	2'928

Figure 5 - Calculations of the power requirements for 3 motor size options

Weights and dimensions of electrical components - Option 1

Component	nr.	Measurements (mm)	Unit Weight (kg)	Total weight (kg)
Battery cabinet	6	1.300x1.300x650	1.000	6.000
Isolation transformer	1	1.200x850x1.200	850	850
Battery charger	1	1.800x2.100x600	650	650
VFD converter	1	900x2.100x730	700	700
Distribution panels	2	600x800x300	50	100
Electric motor	1	1400x750	2.100	2.100
Electric cables and cable runs	Set		3.000	3.000
TOTAL				13.400

Weights and dimensions of electrical components - Option 2

Component	nr.	Measurements (mm)	Unit Weight (kg)	Total weight (kg)
Battery cabinet	13	1.300x1.230x650	1.000	13.000
Isolation transformer	1	1.450x1.000x1.400	1.700	1.700
Battery charger	1	2.400x2.100x600	950	900
VFD converter	1	1.200x2.100x800	1.100	1.100
Distribution panels	2	600x800x300	50	100
Electric motor	1	1.800x1.100	3.200	3.200
Electric cables and cable runs	Set		4.500	4.500
TOTAL				24.500

Weights and dimensions of electrical components - Option 3

Component	nr.	Measurements (mm)	Unit Weight (kg)	Total weight (kg)
Battery cabinet	24	1.280x1.300x650	1.000	24.000
Isolation transformer	1	2.000x1.500x1.900	3.400	1.700
Battery charger	1	4.800x2.100x600	1.900	1.900
VFD converter	1	2.000x2.100x800	1.800	1.800
Distribution panels	2	600x800x300	100	200
Electric motor	1	2.600x1.500	5.000	5.800
Electric cables and cable runs	Set		4.500	6.000
TOTAL				41.400

2 Work objectives

The primary expected outcome is the elimination of CO_2 production and other pollutants resulting from the use of fossil fuels. It is SNL's vision that, by the end of the fleet retrofitting, we aim to reduce the direct CO_2 emissions of our fleets on both lakes by approximately 72% (16,858 tonnes) over the course of the project, leaving us with 0 direct emissions at the end. From 2035 onwards, SNL will continue to serve its customers as it always has, but with the elimination of air pollution caused by its boats.

For the scope of retrofitting the MN Ceresio, SNL aims to obtain an electric boat capable of navigating in the same manner as conventionally powered boats, maintaining the current operational capabilities and characteristics. Additionally, SNL seeks to develop expertise in the electrification process to ease the retrofitting our remaining fleet, while creating new jobs related to the retrofitting. During our testing, SNL has determined that the MNE Ceresio can navigate at an average cruising speed of 20 km/h under maximum load conditions for roughly 6 hours and at slightly lower speed of 19 km/h for up to 8 hours. This includes the need to slow down in crowded areas and near the shore, and the need to accelerate up to cruising speed on the open lake. The vessel will be able to be charged fully in less than 30 minutes at the 2MW charging station at the Lugano Centrale Pier (designed to achieve the shortest charging time possible) and in 5 hours at the shipyard (slow charge). Future boats with larger battery capacity will obviously take longer to charge, however the MNE Ceresio gives us good baseline to determine how our larger ships will behave when charging. An important side goal of this project we have achieved is attention from other navigation companies, showing interest in moving from old generation propulsion systems to newer, more ecological systems.
To summarize, the project objectives consisted of the following:

1. Feasibility Assessment:

- Conducting a comprehensive feasibility study to assess the suitability of retrofitting the vessel from diesel to electric propulsion.
- Evaluating factors such as vessel size, hull design, power requirements, and operational considerations to determine the feasibility of the retrofit, providing valuable information and competence for future retrofitting.

2. Electric Propulsion System Design:

- Designing an electric propulsion system tailored to the specific requirements of the vessel and according to DE-OCB.

- Selecting appropriate electric motors, power electronics, and battery systems based on factors such as power output, efficiency, and space constraints.
- Integrating the electric propulsion system seamlessly into the existing vessel structure while ensuring compliance with safety and regulatory standards.

3. Removal of Diesel Engine:

- Carefully dismantling and removing the existing diesel engine and associated components from the vessel.
- Conducting thorough inspections to assess the condition of the vessel's propulsion system and identify any necessary repairs or modifications.

4. Installation of Electric Motor and Components:

- Installing the electric motor, power electronics, battery systems, and associated control systems in the vessel.
- Ensuring proper alignment and integration of all components to optimize performance and efficiency.
- Implementing necessary modifications to the vessel's propulsion system, including shafting, propellers to accommodate the electric motor.

5. Electrical System Integration:

- Integrating the electric propulsion system with the vessel's electrical infrastructure, including power distribution, control, and monitoring systems.
- Establishing communication protocols and interfaces between the electric propulsion system and other onboard systems for seamless operation and monitoring.

6. Testing and Commissioning:

- Conducting comprehensive testing and commissioning of the electric propulsion system to ensure functionality, reliability, and safety.
- Performing sea trials to assess the performance of the vessel under various operating conditions and verify compliance with regulatory requirements (for example: emergency stop).
- Fine-tuning system parameters and conducting any necessary adjustments or optimizations to optimize performance and efficiency.

7. Training and Maintenance:

- Providing training to vessel crew and maintenance personnel on the operation, maintenance, and troubleshooting of the electric propulsion system.
- Developing a comprehensive maintenance plan and schedule for the electric propulsion system to ensure long-term reliability and performance.
- Compensate the CO_2 offset where possible

3 Approach adopted and current state of knowledge

Due to the complexity of the project, similar projects require teamwork, and a level of expertise on many sectors. The vessel and pier electrification consists of expertise requirements in many different sectors, not only naval, but also electrical, hydraulic, civil engineering, etc.
An additional idea of the project is to support the development of the SNL team; therefore, it was important to integrate as many people as possible on initial or decision-making calls to share knowhow between different teams and companies. Important in this aspect of self-improvement is the training and knowledge from various experts, in our case, the main supplier, Baumüller. Crucial support was also given to SNL by the UFT, especially during the final phases of the project.

4 Results

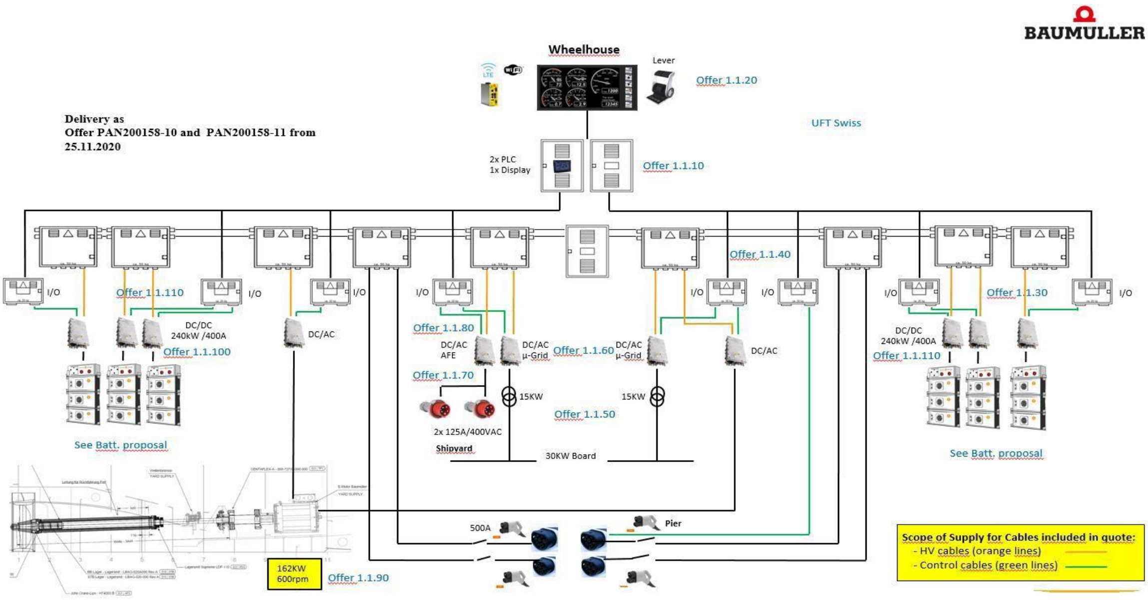

Figure 6 - MNE Ceresio commercial schematic

4.1 Operating modes

The ship has 3 operating modes:

- Full-electric sailing, for when the ship draws power to navigate
- AC charging, for slower charging at the shipyard
- DC charging, for use at the fast charge stations

The operating modes can be preselected via the touch control terminal (Figure 7).

Figure 7 - HMI page on the control panel to choose the charge method

While normal operation of the vessel is controlled through these 3 pre-set modes in the computer system, manual operation for special driving situations has also been implemented, controlled via a drive lever.

A) Battery Full-Electrical Sailing:

During full-electrical sailing, both the propulsion motor and the onboard network draw power from six battery packs. The discharge of these batteries occurs evenly, ensuring sustained and balanced energy supply throughout the sailing duration.

B) AC Charging at the Shipyard:

Charging the battery at the shipyard is facilitated through two 125A CEE AC plugs. This charging process is automated, continuing until the battery reaches its predetermined capacity, thus streamlining the charging procedure and ensuring optimal battery performance. This charging process does not override the battery, so the ships onboard systems are still powered by the battery while charging.

C) DC Charging on the Pier:

Charging the battery on the pier involves utilizing four oil-cooled CCS2 plugs capable of delivering a maximum of 500A of DC power. The AC/DC converter, situated on the pier, features a user-friendly front panel to which charging cables are connected. During the charging process the plug connection is securely locked electromechanically to enhance safety. As with AC charging, the DC charging process is automated, stopping only when the battery reaches its predetermined capacity. To initiate charging at the pier, the user specifies the desired charging power through a user-friendly menu integrated into the ship's Power

Management System (PMS), ensuring seamless integration and control over the charging process. This charging process does not override the battery, so the ships onboard systems are still powered by the battery while charging.

4.2 Drive motor

The drive motor has been selected based on the characteristics of the engine motor. For this reason, Baumüller provided a motor with high torque at low RPM.

V (km/h)	RPM	kW	Torque (Nm)
13,3	252	24	909
20,5	409	112	2615
22,2	461	168	3480

Figure 8 - Motor operational specifications for different navigation speeds

To meet these needs, SNL selected the DST2-260 motor line, as it was determined to best fit the requirements. As this motor could delivery up to 250 kW of power, SNL has electronically limited the power to 168 kW, as this was the maximum power required for our navigational uses (Figure 8).

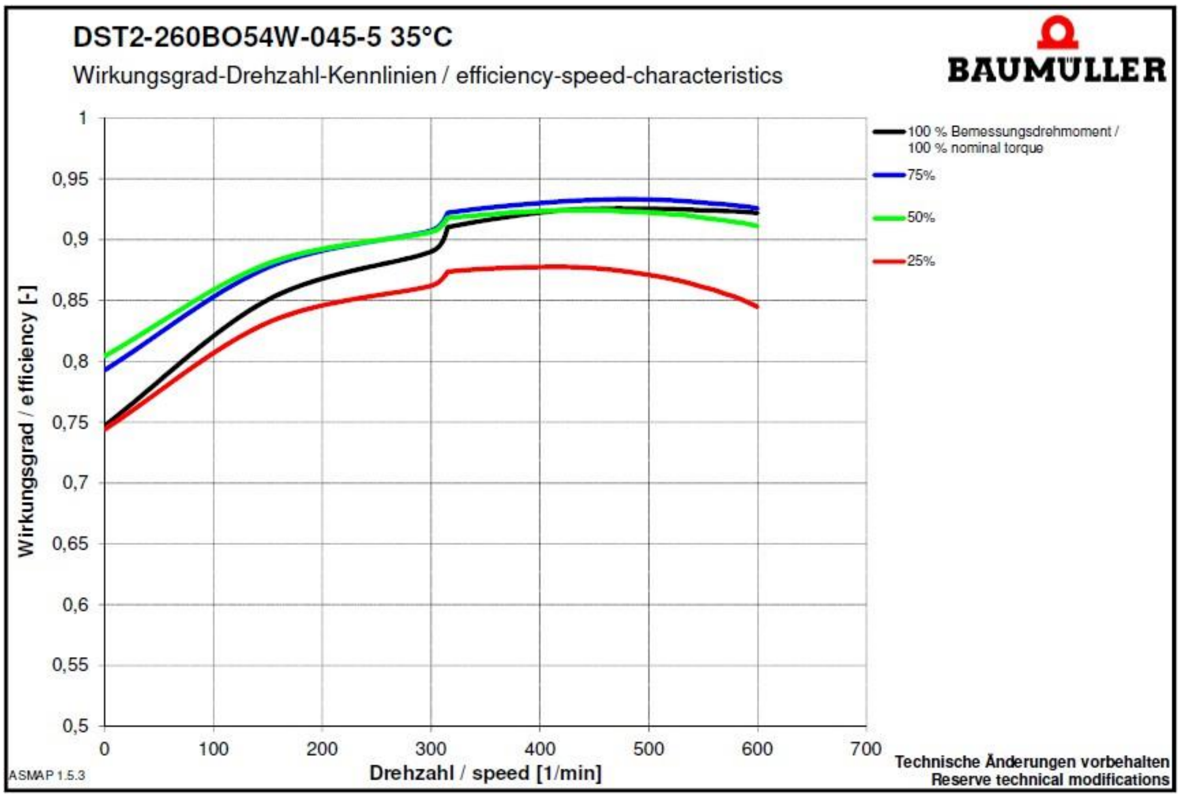

Figure 9 - Baumüller motor efficiency displaying the relationship between the torque of the motor and speed.

4.3 HV-Battery

The battery system feeds the direct current intermediate circuit through 6 DC/DC converters. The power required was determined by the demands of the drive motor and the onboard network consumers. The design featuring 6 DC/DC converters was chosen to enable rapid charging of the battery, ensuring it reached its maximum charging capacity efficiently. Charging of the battery occurs either at the central pier, utilizing the DC Fast Charging infrastructure, or overnight at the shipyard via the AC connection. The battery system selected consists of 6 air cooled modules of 18 lithium-ion cells, providing up to 840 kWh of power.

System basic properties	single cell			System Total	
System maximum voltage	128	V		768	V
System Nominal Voltage	115	V		690	V
System minimum voltage	96	V		576	V
System minimum operational voltage	80	V		480	V
Total system usable energy content +- 2%	6	kWh		671	kWh
Total system nominal energy content +- 2%	8	kWh		840	kWh
System nominal peak power (<10s)	35	kW		3732	kW
System nominal continuous power	17	kW		1867	kW
System nominal charge peak power (<8min)	16	kW		1679	kW

Figure 10 - Basic properties of the battery system

System Specifications:

Total System Energy (+-2%)	840	kWh	**Model**	Dolphin Power
Design Life	10	Years	**Battery Modules x packs**	6 x 18
Maximum Voltage	768	V_{DC}	**pack Configuration**	Vertical/Horizontal
Minimum Voltage	576	V_{DC}	**pack footprint**	655 mmL x 345 mmD
Total Dry Mass (+-5kg/pack,)	6.516	kg	**pack height**	2070 mmH

Figure 11 - System specifications of the selected HV battery pack

Returning to section 1.2 of this report, regarding the vessel requirements, SNL conducted simulations to assess the battery capacity needed for the same journey, aiming to precisely determine the battery requirements (Figure 12). While the analysis done in section 1.2 was intended to determine our theoretical power requirements for the engine, this simulation was focused on confirming that the specific choice of battery would be sufficient for a realistic day's use, including periodical charging. After determining the appropriate quantity, we conducted mechanical checks using mock-ups to ensure that all the batteries, battery racks, and cooling systems could be accommodated in the battery rooms.

Time of Day	Time in min	Movement	Descrition	Power E-Motor	Energy
		Start with fully charged battery			**671**
08:11:00	10	Step 1	Cantiere - Lugano - 12km/h	-68	-11,3
08:21:00	9	Step 2	Stop in Lugano	-5	-0,8
08:30:00	36	Step 3	Lugano - Porto Ceresio - 21,5km/h	-172	-103,2
09:06:00	9	Step 4	Stop in Porto Ceresio	-5	-0,8
09:15:00	36	Step 5	Porto Ceresio - Lugano - 21,5km/h	-172	-103,2
09:51:00	9	Step 6	Stop in Lugano	-5	-0,8
10:00:00	36	Step 7	Lugano - Porto Ceresio - 21,5km/h	-172	-103,2
10:36:00	9	Step 8	Stop in Porto Ceresio	-5	-0,8
10:45:00	36	Step 9	Porto Ceresio - Lugano - 21,5km/h	-172	-103,2
11:21:00	9	Step 10	Stop in Lugano	-5	-0,8
		battery status after 03.19 hours cruising			**243,1**
11:30:00	**19**	**Fast-Charging I:**	**1120kWh with an Efficiency of 96,2% at EOL**		**354,7**
		battery status after charging: 89 %			**597,8**
11:49:00	60	Step 11	Sight Seeing 1h with - 21,5km/h	-172	-172,0
12:49:00	90	Step 12	Sight Seeing 1,5h with - 12km/h	-68	-102,0
14:19:00	90	Step 13	Sight Seeing 1,5h, Multiple Stops	-5	-7,5
		battery status after 04.00 hours cruising			**316,3**
15:49:00	**19**	**Fast-Charging II:**	**1120kWh with an Efficiency of 96,2% at EOL**		**354,7**
		battery status after charging: 100 %			**671,0**
16:08:00	9	Step 14	Stop in Lugano	-5	-0,8
16:17:00	36	Step 15	Lugano - Porto Ceresio - 21,5km/h	-172	-103,2
16:53:00	9	Step 16	Stop in Porto Ceresio	-5	-0,8
17:02:00	36	Step 17	Porto Ceresio - Lugano - 21,5km/h	-172	-103,2
17:38:00	9	Step 18	Stop in Lugano	-5	-0,8
17:47:00	36	Step 19	Lugano - Porto Ceresio - 21,5km/h	-172	-103,2
18:23:00	9	Step 20	Stop in Porto Ceresio	-5	-0,8
18:32:00	36	Step 21	Porto Ceresio - Lugano - 21,5km/h	-172	-103,2
19:08:00	9	Step 22	Stop in Lugano	-5	-0,8
19:17:00	10	Step 23	Cantiere - Lugano - 12km/h	-68	-11,3
		battery status after 03.19 hours cruising			**243,1**
19:27:00	**686**	**Charging night:**	**39kWh with an Efficiency of 96,2% at EOL**		**428,0**
06:53:00		**Vessell Ready for Usage**			**671,1**
		total consumption over one day			**-1137,3**

Figure 12 - Simulation results to determine the battery capacity requirements in kWh

Using the performance efficiency of the system, we calculated the additional power needs to operate the vehicle, considering factors such as the lighting, cooling, and other electrical systems aboard the boat (Figure 13). We added 6.63 kWh to meet these needs. The calculations have been made using real power consumption, adjusted for the 98% efficiency of the electrical converter.

Powertrain Performance	
Motor Efficiency	0.93
Converter Efficiency	0.98
Battery Efficiency	0.99
Board-Net Performance	
Converter Efficiency	0.98

Ship electrical balance	kw
Battery cooling	2
Interior air conditioning	3
Liquid cooling - motor el.+ conv	0.5
Lighting	0.5
Navigational systems	0.5
Total	6.5
Total accounting for efficiency losses	**6.632653**

Figure 13 - Additional power requirements excluding powering the motor

4.4 Fast charge station

4.4.1 Introduction

The electric boats currently in SNL's fleet can be recharged in two ways, using an Alternating Current (AC) charge, which is slower, or a Direct Current (DC) charge, which is significantly faster. While AC charging can be done much more simply, connecting to the main power grid, DC fast charging requires a transformer station.

AIL SA was originally asked to supply a transformer cabin that could provide 2MW of low voltage electricity, but due to the transformers in use by AIL, they were only able to supply 1.5MW. While this is lower than the original request, it's been determined that this will still be suitable for the needs of SNL. It is recommended to begin charging with no less than 20% residual power remaining in the battery, and to not exceed 80% of the capacity to maintain the lifespan of the battery. This means that maximum power required to charge the MNE Ceresio is 60% of the battery's total capacity of 840 kWh, which results in 504 kWh. Using the 1.5MW fast charging station therefore can theoretically supply this power in roughly 20 minutes (504kWh/ 1500kW = 0.336 hours, or 20.16 minutes). Considering that during the start of the charging phase there will be a rebalancing activity of individual cells that could slow down the process and, despite the battery room being cooled, a thermal increase could lead to inefficiencies, we apply a 10% extra time buffer, leading to a 22-minute theoretical time for a full recharge, though this could be subject to further slowing caused by additional rebalancing or hotter temperatures in the summer. Charging the cells at this maximum rate, however, can lead to faster degradation of the batteries, so in order to preserve the longevity of the batteries Baumüller has included a system which automatically reduces the charge rate based on the charge state of each cell. This reduced charge rate will result in a realistic charging time of roughly 30 minutes. Results of the fast-charging tests can be found in section 4.4.6 of this report.

This transformer station was completed in May 2024 by AIL at the main pier of Lake Lugano, but at the recommendation of ESTI Ticino the current TN-C network will be converted to an IT network (Section 4.4.4). Once these modifications have been completed, it will be transferred to SNL SA for management. The power currently installed is 2500 kVA with two 1250 kVA transformers, and the transformer cabin can be located on Lugano's RFD maps 234 and 309. As part of the renovation work on the pier an electricity supply point was created exclusively for charging the boats of SNL.

Figure 14 - The fast-charging station on the Lugano Centrale pier

4.4.2 Location

The transformer station is located on the lakefront of Riva Vincenzo Vela, right next to the central pier.

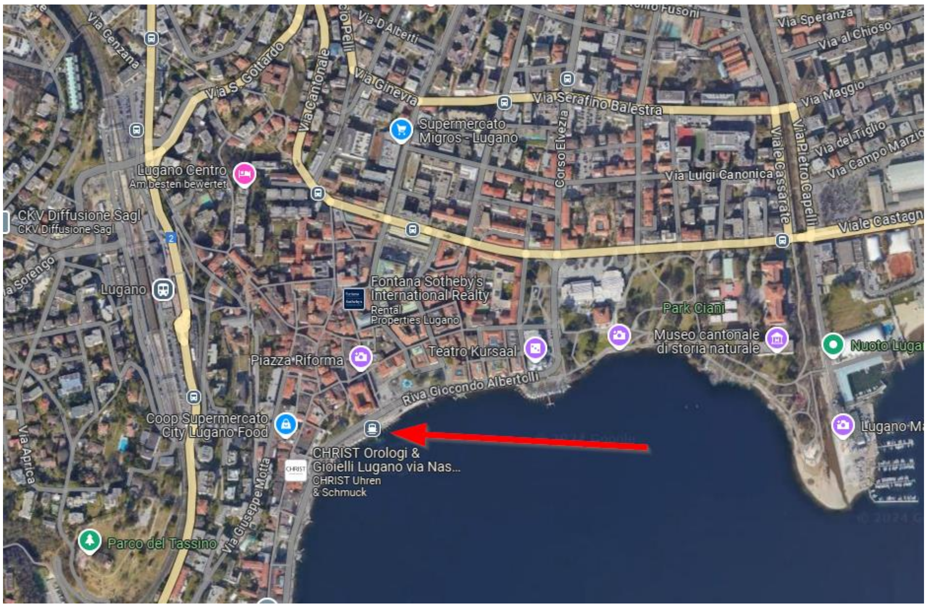

Figure 15 - Location of the transformer station on the lakefront

Cabin 1350 Lugano Pier:

- municipality: Lugano
- coordinates: 46° 00' 11" N / 8° 57' 06" E
- altitude: 271.08 m a.s.l.

Figure 16 - Transformer cabin next to the central pier

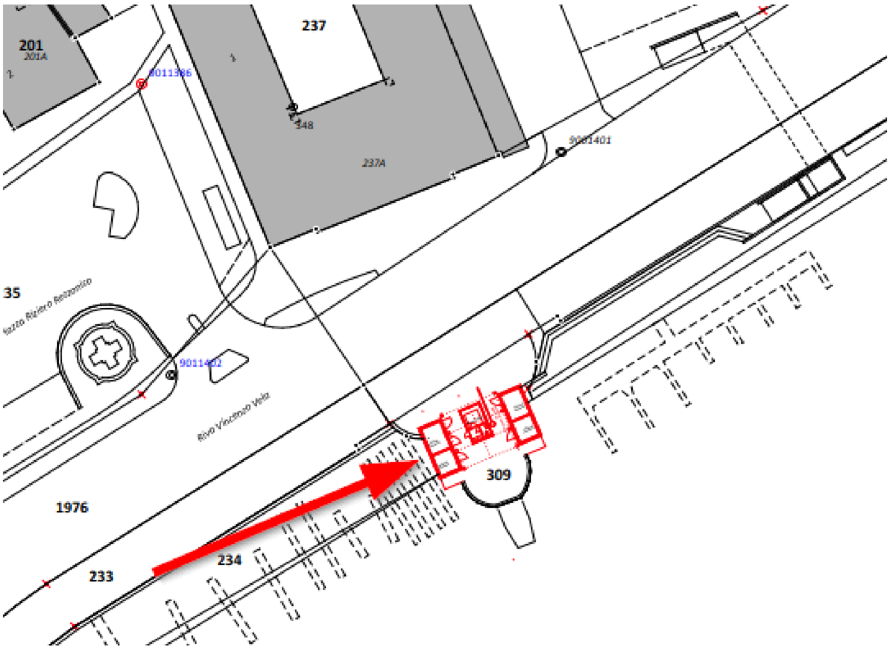

Figure 17 - Current transformer cabin of AIL

4.4.3 Construction and implementation

Considering the size of the two 1250kVA (16.8kV / 420 - 230V) transformers required for the operation of the installation, as well as the necessary equipment for energy management and distribution, the overall dimensions required for the new transformer cabin are 7.00 m long by 3.00 m wide.

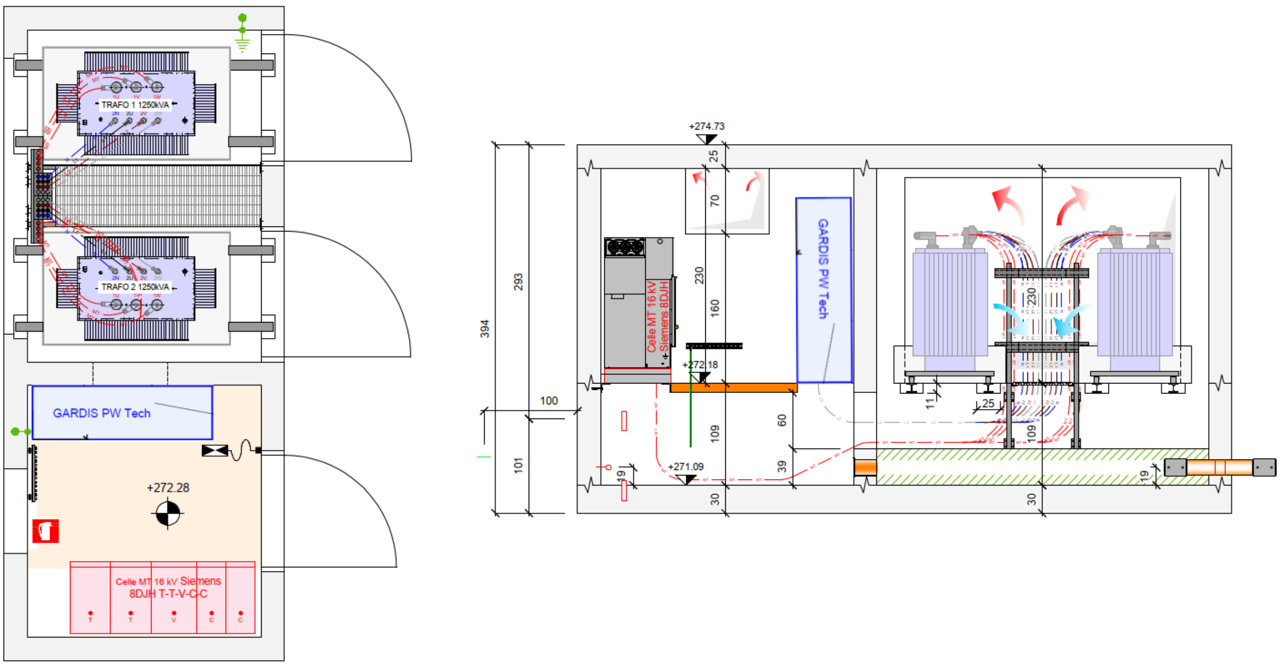

Figure 18 - AIL transformer cabin plan with the new MT and BT switchboards

The structure is divided into two compartments, one of which is used to house the transformers (net dimensions in plan: 3.55 m by 2.50 m) and a second room used for electrical and fibre optic equipment (net dimensions in plan: 2.70 m by 2.50 m), for optimal management of the cabin.

The approval for the cabin was studied and requested for operation at maximum power and for this purpose there are two 1250 kVA transformers for a total of 2500 kVA. These are equipped with a stainless-steel tank, each for containing the oil, with a 100% capacity of approximately 860 L (average content of a 1250 kVA transformer is max. 820 L), all in compliance with current regulations. Transformers containing MIDEL oil (vegetable oil) as insulation were installed.

With regard to the ORNI regulations concerning non-ionizing electromagnetic fields, given the delicate nature of the location (proximity to the ticket office), it is necessary to equip the booth with shielding in order to reduce emissions to bring them within the legal parameters.

On the advice and in agreement with SNL SA, the ticket office is shielded to isolate the room from non-ionizing radiation also coming from the AC/DC rectification system. The entire structure is constructed using “Drytech tank” technology, reinforced concrete and the above-ground facades are covered with metal slats (see the pier redevelopment project). The roof slab is waterproofed using suitable resin, roof water is disposed of in the surrounding land. Access for maintenance and repair work will be from Riva Vincenzo Vela.

Figure 19 - The electrical system inside the structure at the pier with the charging control interface

4.4.4 Principal points of the system

The transformer cabin currently provides a TN-C network for downstream consumers but following the indications of ESTI Ticino it will be adapted into an IT network (isolated ground system) soon. The IT network will be used exclusively for the charging system produced by the Baumüller company, principally for the charging of electric boats. The transformers will be maintained and only the medium and low voltage switchboards will be adapted.

For other purposes that requires a regular voltage, for example the ticket office, a separate TN-C network is provided by AIL SA from the municipal cabin. This power supply will also provide power for the sockets and lights in the two lateral structures, which are the transformer cabin and the cabin containing the AC/DC rectification system.

4.4.5 Security measures

The safety of people and the system is ensured by the integrated IMD (Insulation Monitoring Device) and the earthing network (See the diagram in Attachment 1). The IMDs are interconnected and serve as the basis for the controlled activation and deactivation of the system, as well as define the behaviour or procedures of the system in the event of a fault.

4.4.6 Fast-charging procedure and testing

Charging the boat using the fast-charging station can be done in multiple ways, depending on the needs of the batteries. The full, fast-charging capabilities of the station can be used with the attachment of all four charging cables to the boat ensuring the safety locks are engaged and activating the charging procedure from either the charging station on the pier, or from the terminal on the boat. Fewer cables can also be used should the full capability of the charging station is not required. Full instructions for the different charging modes and required safety procedures can be found in the attached guide (Attachment 8).

Figure 20 - The 4 400A charging cables of the fast-charging station

Preliminary testing was carried out on the batteries to determine how the real-world charging speed would compare to the calculated theoretical speed, and as anticipated the system designed to preserve the longevity of the batteries slowed the charge rate as the charge level increased, resulting in a full charge (60% of the full battery capacity) from 10% to 70% in 30 minutes. This represents 10-70% of the battery’s full capacity, not just the normal usage range confirming that the fast-charging station can recharge the MNE Ceresio in a timeline similar to the theoretical calculations in real-world conditions, which as calculated in section 4.4.1 of this report is roughly 22 minutes. The slightly slower charging time of 30 minutes is due to warmer temperatures causing the charger to automatically throttle the speed for safety reasons, and all 6 cells not beginning the process at an equal charge level, slowing the charge as the system needed to balance the charge across them.

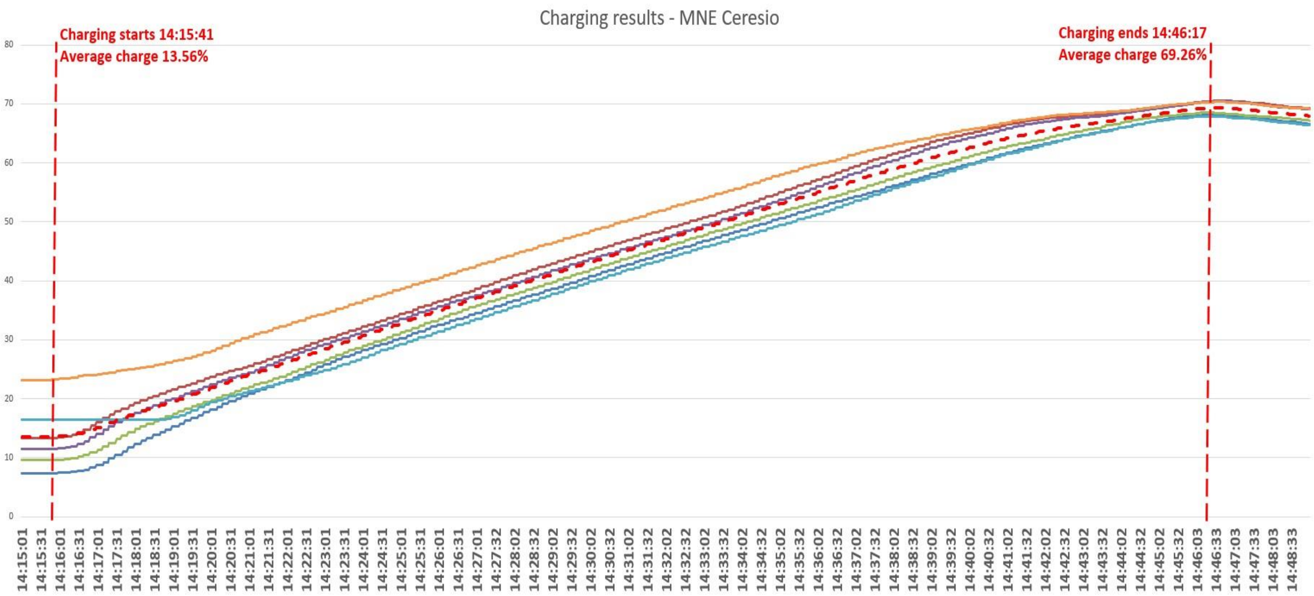

Figure 21 - Results of the recharge test displaying the charge level of each of the 6 battery cells over time

4.5 Shipyard charging system (AC)

The AC shore connection plays a pivotal role in maritime operations, facilitated by a shore connection converter. This converter serves a multifaceted purpose, primarily enabling the charging of ship batteries while docked at the shipyard. Beyond its fundamental function, it offers versatility by accommodating various charging requirements and power needs essential for maritime operations. At the shipyard, the vessel's charging needs are met efficiently through an AC charging mechanism utilizing a standard industrial plug, characterized by its five poles. The charging infrastructure is robust, comprising two plugs capable of delivering a substantial power supply of 125A each. This setup ensures expedited charging processes, catering to the vessel's power demands effectively. By leveraging this sophisticated AC shore connection setup, maritime operations benefit from enhanced efficiency and reliability. The system not only facilitates seamless charging of ship batteries but also supports auxiliary functions critical for shipyard operations. Due to this additional function increased power was required, therefore the shipyard now has up to 630A available in AC.

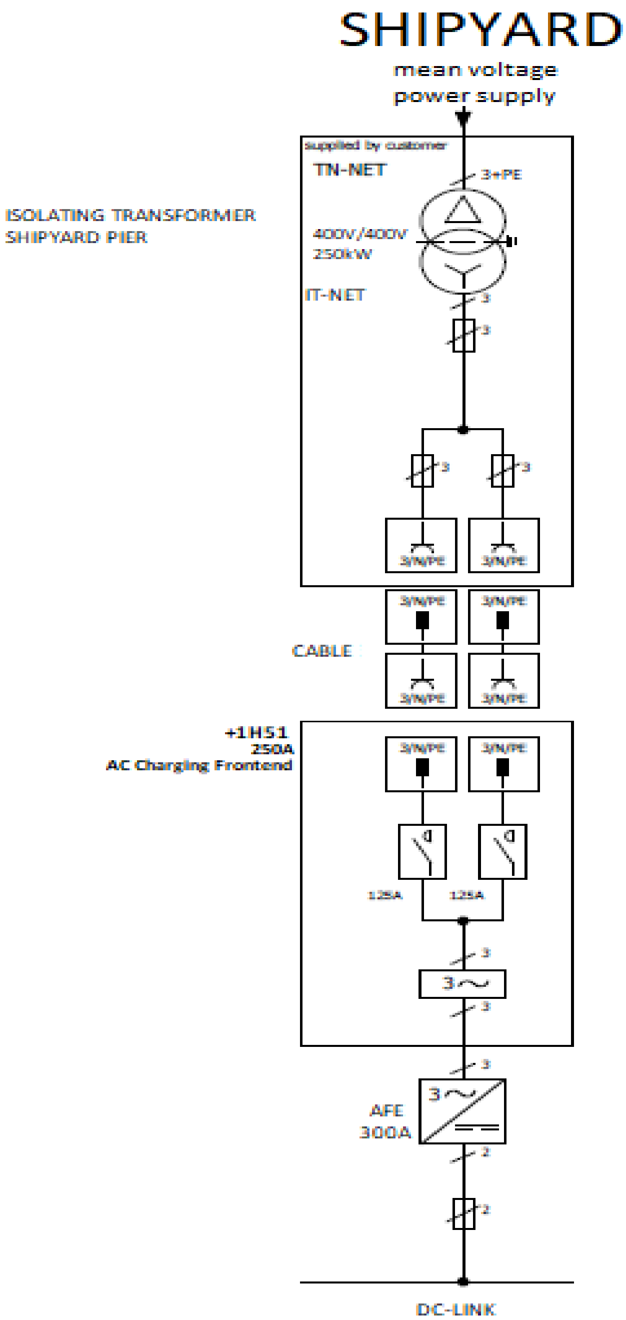

Figure 22 - Shipyard wiring schematic

4.6 Power supply for onboard systems

The onboard power supply system boasts redundancy, ensuring uninterrupted energy supply for critical operations. Energy extraction from the intermediate circuit is facilitated by a DC/AC converter. This converter's AC output is channelled into the vehicle's electrical system through a sinusoidal filter and a transformer, guaranteeing stable and reliable power distribution. Notably, the onboard power system comprises two independent units, each with its own switch for individual activation and deactivation. In the event of a failure in one of the units, seamless continuity is maintained as both networks can function with just a single operational onboard power supply, mitigating downtime and maximizing operational efficiency. Furthermore, the Power Management System (PMS) is equipped with a dedicated 24V power source, ensuring autonomous functionality. This power supply is sustained by a 24V power supply unit during standard operations, reinforcing system reliability. Moreover, the cooling systems crucial for maintaining optimal operating conditions are directly powered by the onboard power supply, underscoring its pivotal role in sustaining critical subsystems. This integrated approach to power management guarantees robustness, resilience, and uninterrupted performance across essential onboard systems.

4.7 Power distribution – DC link

The drive system's energy distribution relies on a shared intermediate circuit, ensuring optimized energy efficiency by supplying power to both the drive system and onboard voltage consumers from the DC link. Compliance with DNV-GL standards mandates a single-fault tolerance design, ensuring system reliability. The intermediate circuit is segmented into two distributions interconnected during standard operation. In case of a fault in one segment, it is promptly isolated while the unaffected segment remains operational, ensuring uninterrupted functionality. Continuous monitoring of the intermediate circuits is ensured through two insulation monitors, adhering to DNV-GL regulations for structural integrity. A dedicated charging circuit facilitates recharging of the intermediate circuit. Basic charging becomes necessary upon discharge, which can occur via either the shore connection or the onboard batteries, ensuring readiness for subsequent operations. This comprehensive approach to energy management guarantees robustness, safety, and compliance with industry standards, enhancing overall system reliability and performance.

4.8 Remote access

Baumüller offers a convenient solution for remote access to the PMS system via an Internet connection facilitated by SNL, allowing for seamless remote service access. A router is installed in the bridge area of the ship, serving as the central hub for network distribution to all participants requiring remote access. To ensure smooth connectivity, the PMS system is responsible for establishing and maintaining the network connection between the engine room and the router located on the bridge. It's crucial for this connection to remain robust and reliable, facilitating efficient communication between onboard systems and remote service providers. However, it's imperative to note that the utilization of remote access capabilities is subject to adherence to data protection laws. Therefore, prior to accessing the system remotely, a user agreement was established between the manufacturer and us, outlining the terms and conditions governing the use of remote access services. This ensures compliance with legal requirements and protects sensitive data from unauthorized access or misuse.

4.9 Cooling system

The systems are efficiently cooled using a water-glycol-filled system, tailored to the contractor's cooling specifications as per client requirements. Primarily, the drive train is cooled independently through a dedicated piped system. A lake water pump serves as the primary source, supplying water to a heat exchanger. Currently the excess heat is expelled from the boat into the water, however for future retrofits SNL will evaluate the possibility of using this excess heat for other functions on the boat, such as interior heating or keeping the batteries at the correct temperature during colder weather. The electric motor and associated power electronics, including the inverter and converter, benefit from a specialized cooling circuit utilizing pure water. This dedicated cooling unit operates with its own expansion capabilities, ensuring optimal performance and temperature regulation for the critical components.

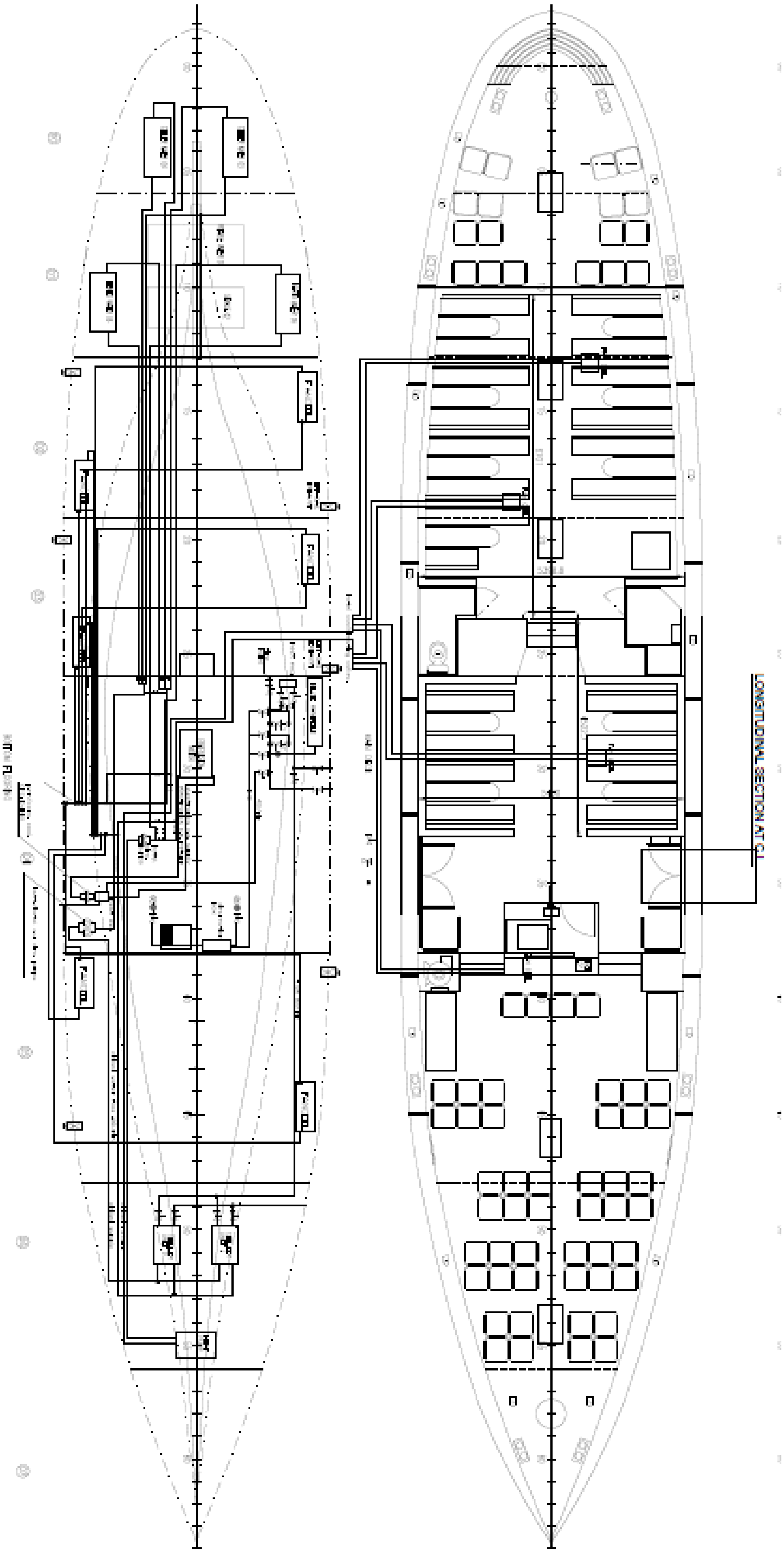

Figure 23 - Battery cooling system and heating, ventilation, and air conditioning system (HVAC)

4.10 Navigation testing

To become fully certified, the MNE Ceresio has been inspected and tested by the competent authority (UFT). To prepare the vessel for the certification the following tests have been performed prior to UFT inspection:

4.10.1 Speed at different power settings

These checks include:

- Monitoring lever position.
- Verifying ship speed.
- Assessing shaft speed.
- Monitoring mechanical torque.
- Analysing current and power levels at the propulsion electric motor (P.E.M.) terminals and P.E.M. converters.

4.10.2 Maximum contractual speed

The maximum ship speed must undergo verification and documentation through two runs of adequate duration; each conducted in opposite directions to counterbalance the effects of wind and currents. It is expected that the speed attained should not fall below 20 km/h when operating at maximum propulsion power under full load conditions.

4.10.3 Crash stop/astern run

At maximum ship velocity, the full reverse thrust is engaged using the "with handle" (W.H.) lever. Subsequently, the stopping distance is meticulously measured through two distinct runs, each undertaken in opposite directions. Upon the ship's complete halt, reverse thrust is maintained until the maximum astern speed is reached. Throughout this process, a comprehensive report must be compiled, detailing various parameters including:

- Ship speed
- Shaft speed
- Mechanical torque
- Current and frequency at the P.E.M. and P.E.M. converters.

These detailed reports serve to ensure the thorough evaluation of the ship's performance during reverse operations, enabling precise analysis and optimization of propulsion systems.

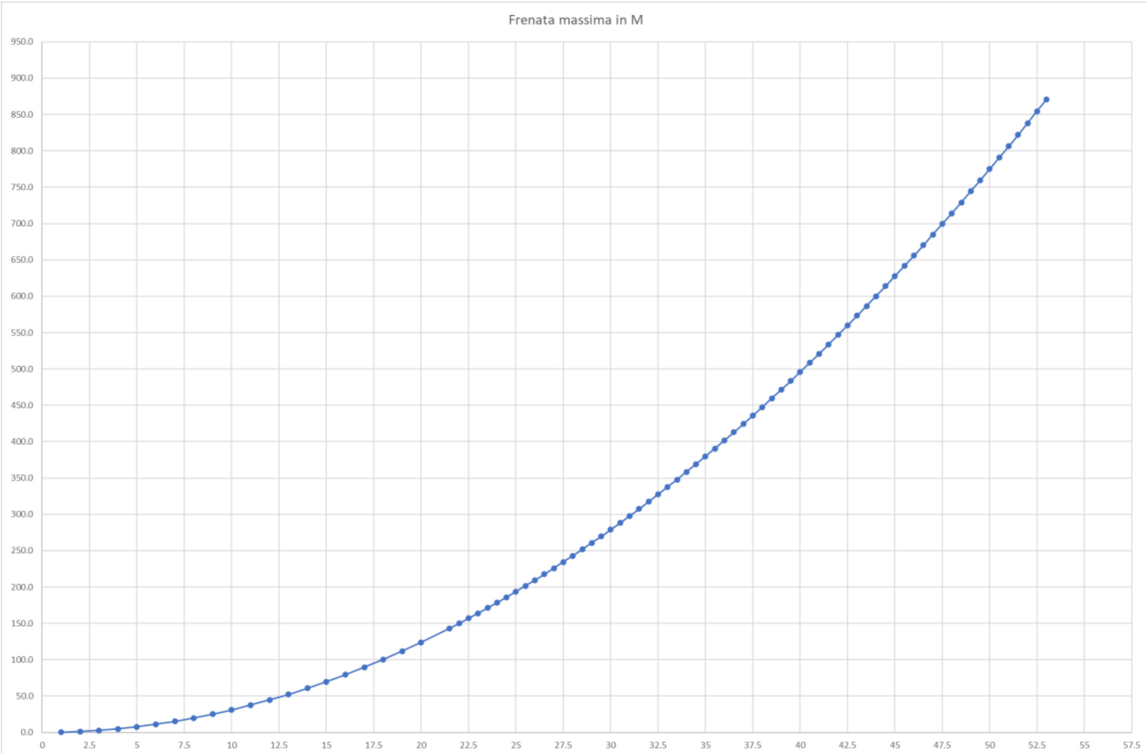

Figure 24 - Braking distance vs. speed. X-axis is breaking distance in metres; y-axis is engine RPM.

4.10.4 Turning circle

This test evaluated the steering gear machinery and rudder performance comprehensively. With the ship operating at full speed, the rudder was commanded to hard port and starboard directions, conducted in two separate runs. Throughout these manoeuvres, the course and speed of the vessel were meticulously plotted and analysed. Additionally, close monitoring of the new propulsion system's behaviour was essential to ensure proper functionality. Any occurrences of propeller ventilation or cavitation were carefully observed. In the event of such incidents, the propulsion system autonomously adjusted by reducing power to maintain correct torque and shaft speed values, thereby optimizing performance and ensuring safe navigation.

4.10.5 Propulsion system efficiency

The verification of both the P.E.M. and system efficiency against contractual requirements was essential. P.E.M. efficiency had to be aligned with the specifications provided by Baumüller, ensuring adherence to performance standards outlined in the contractual agreement. Additionally, converter efficiency was required not to dip below 97% when the vessel was sailing at steady speeds. This stringent criterion guaranteed optimal system performance and energy utilization during operational conditions.

4.10.6 Electric storage system (ESS) performance

Specifically, it focused on sustaining various loads such as propulsion power, power for the battery modules cooling system, and onboard system loads (excluding HVAC for the interior) using the ESS to achieve the performance outlined in Baumüller's offer and calculations.

- Measurement of the stored energy in the ESS at the beginning of the test.
- Execution of the sailing/cruise profile as specified.
- Measurement of the stored energy in the ESS at the end of the test.
- Verification of the accuracy of the residual charge indication on the bridge.

4.10.7 Electric loads balance

To evaluate the performance of the DC/AC converter, both hotel net and emergency net loads were applied. These loads encompassed a range of power demands, thereby assessing the converter's capability across various scenarios. The DC/AC converter was subjected to diverse loads within the inverter's power range. Additionally, the 230-volt consumers were evenly distributed across the three-phase AC system, ensuring balanced utilization and optimal operation of the converter.

4.10.8 Tests for safe return to pier end operational redundancy

The ship's ability to navigate in the event of a critical component failure within the electrical propulsion system was confirmed. This included failures such as those in the PEM winding, PEM converter, propulsion PLC, battery module, or control lever encoder. Additionally, the behaviour of the DC system was verified in scenarios where one or two battery rooms were disconnected from the grid. The ship demonstrated the capability to sail with only one battery room connected to the grid, provided there was sufficient energy stored in the batteries. Verification also entailed determining the maximum attainable speed when operating with just one battery room connected to the grid.

4.10.9 Propulsion system and battery management system interface with fire detection and extinction system

The ship is equipped with a fire detection system and a fixed fire extinguishing system inside battery rooms and the electrical switchboard room. Proper communication between the PMS, BMS, and fire systems was verified in case a fire was detected, or fire extinguishing media was released. Potential free contacts were provided to the PLC, indicating status such as ok/not ok fault.

4.10.10 UFT Certification and test results

On the 14th of September 2021, after the testing period was completed, it was deemed by the UFT that the MNE Ceresio had passed the tests and meets the requirements for certification. SNL was granted a temporary certification lasting until December 2021, and upon completing this trial period, and resolving final minor remarks and concerns of the UFT, the MNE Ceresio was granted its full certification. (See Attachments 2 through 5). After completing this testing phase and achieving these certifications, SNL has not only proven that the boat can be operated in the same manner as it was when powered with a diesel motor, but performance has notably increased.

4.10.11 Comparative testing – Consumption and operating costs

In May and June of 2025, the MNE Ceresio underwent various trials to obtain comparative performance data versus the previous Detroit Diesel 8V-71 motor. These tests were focused on the performance of both engines at the typical cruising speed of 21.5 km/h, as well as the associated operating costs and CO_2 emissions of the 13km Lugano – Porto Ceresio route. The full report containing the details of the results summarised here can be found attached to this report (Attachment 7, Italian).

The results of these tests have shown a significant savings in operating costs, with a ~13% reduction from ~37.80 CHF to ~33.- CHF per 13 km trip. With an estimated 1'000 trips following this route every year, this represents a savings of almost 5'000 CHF annually, or for the 10-year horizon of this project, up to 50'000 CHF. Additionally, fossil fuel prices have historically been subject to high volatility, particularly in recent years, while the electricity in Switzerland can be produced from local, renewable sources, offering advantages to future price stability and environmental benefits.

In addition to the economic benefits, the new electric motor offers drastic ecological improvements, particularly in the reduction of CO_2 emissions compared to the previous diesel engine. Using average emission factor for diesel engines of 2.65 kg of CO_2 per litre of diesel, and a consumption of 27 L of diesel per 13km route, we see emissions of ~72 kg of CO_2 per trip. Projecting for 1'000 trips of this route per year, this amounts to annual emissions of approximately 72 tons of CO_2. The new electric motor, however, emits no CO_2, equating to a 100% reduction in emissions, eliminating all 72 tons of CO_2 of direct emissions on an annual basis. It should be noted that this reduction is purely based on tailpipe emissions from the operation of the boat, not accounting for CO_2 generated by the electricity production, however the Swiss electricity grid already uses a low-emission energy mix, with a high reliance on local hydroelectric energy, therefore provides a significant reduction in overall CO_2 emissions even when accounting for electricity production. This also means that the total rate of emissions of the MNE Ceresio will decrease even farther over time as improvements are made to the Swiss energy grid.

Apart from the elimination of CO_2 emissions, the new electric motor provides other significant benefits to the MNE Ceresio, such as:

- Elimination of local pollutant emissions such as Nitrogen Oxide (NO2), fine particulate matter (PM10 and PM2.5), and other pollutants (SO_X CO, unburned hydrocarbons).
- Noise and vibration reductions, as electric motors run much quieter and smoother than

internal combustion engines.

- Benefits to the aquatic ecosystem by eliminating the risk of spills of diesel fuel and oil to eliminate the introduction of hydrocarbons into the water, and the absence of hot engine exhaust eliminates the risk of thermal impact.
- As the electric motor has fewer mechanical parts, wear on the engine is significantly reduced, and routine maintenance needs to be carried out less frequently.

4.11 Fire protection

To ensure safety, the battery rooms and electric switchboard compartment were equipped with fire protection systems in accordance with UFT DE-OCB requirements and additional specifications mandated by UFT, which considered DNV-GL rules for seagoing vessels. Notably, the ceiling area of the battery rooms was designated as zone 2, with no air ducts leading to other compartments installed within them. Furthermore, a comprehensive FIRE PLAN was incorporated into the fire report, encompassing both active and passive fire protection measures, with specific attention given to the fire protection of the battery rooms. In terms of passenger accommodations, all ceiling and bulkhead panels in the passenger rooms were replaced with Alucore panels made of aluminium, known for being non-combustible and MED approved (N° MED121916CS/002). Additionally, the seats in the passenger rooms were substituted with materials compliant with DE-OCB requirements, characterized by low flame spread and smoke emission properties.

4.11.1 Ventilation

A forced air ventilation system has been installed in the electric switchboard room, allowing for ventilation control from both inside and outside the room. Fire dampers are strategically placed with automatic closure mechanisms in the event of a fire, ventilator shutdown, or discharge of the inert gas system. Each battery room is equipped with an emergency ventilation system featuring forced air induction and manual fire dampers. Under normal conditions, the system remains inactive with fire dampers closed to prevent external air particulates from contaminating the batteries and voiding their warranty. However, the system can be manually activated in the event of hydrogen gas detection. Furthermore, blowers are positioned outside zone 2, and steel ducts are installed to expel contaminated air into the atmosphere (open deck), ensuring sufficient air changes and maintaining a safe environment.

4.11.2 Passive fire protection

The original all-wooden internal deck has been replaced, with a continuous 5mm thick steel deck being welded in place to provide A60 fire resistance for the battery rooms and electrical switchboard room ceiling. Paroc fire slab 100 has been utilized in this process. A60 fire insulation has been installed inside the electric switchboard room and battery rooms in accordance with SOLAS requirements. The thickness, density, and certification of the glass wool insulation have been carefully verified to ensure compliance. In line with SOLAS requirements, exposed steel elements can be observed on the ship's insulated ceilings and bulkheads, limited to specific fire-exposed surfaces. For instance, cable tray brackets, pipes with a diameter less than 65mm, and small sections of the ship's structural members are exempt from fire insulation. Additionally, A60 fire insulation has been applied to the ship's shell plating at the request of UFT, extending up to the lowest immersion waterline, although not mandated by SOLAS regulations. To prevent water dripping and detachment, A60 fire insulation has been installed on bulkheads from the ceiling to the bilge floor level, omitting the ship's bottom level. This precautionary measure is considered best practice in marine shipbuilding to prevent the potential plugging of the bilge system with glass wool residue.

4.11.3 Active fire protection

MNE Ceresio is equipped with three active fire protection systems:

- A pressurized lake water mains system, supplied by a high-pressure, high-capacity multistage fire pump (FEIT TSL 25/1). Additionally, an emergency diesel-driven fire pump (AIRMEC HL 50 CXL 2E) is installed as for backup.
- An inert gas system with dual charge for the battery rooms and a single charge for the electric switchboard room.
- Hand-held portable fire extinguishers (powder, foam, and CO_2) in compliance with DE-OCB art. 39-1.

The fixed inert gas suppression system complies with DE-OCB 39.5, and a fire protection (response) plan and abandon ship plan have been issued by SNL.

The explanation clarifies that the limitation in vessel length was established by regulations and does not reflect the fire protection capabilities of the systems. Additionally, it emphasizes that the world reference standard for design, installation, and maintenance of clean agent systems is NFPA12, which does not impose limits on the application of pre-engineered systems based on vessel length. The fire tests of pre-engineered systems are based on the protected space volume and enclosure, rather than vessel length, ensuring effective protection regardless of vessel size.

4.11.4 Fire detection

An onboard fire detection system featuring dual sensors (smoke and temperature) has been installed. Capable of monitoring up to 8 distinct areas, zone 2 rated sensors are specifically placed in the battery rooms. The control and alarm panel are strategically located in the wheelhouse for easy access and monitoring.
The covered areas include:

- Battery room 1
- Battery room 2
- Battery room 3
- Electrical switchboard room
- Toilet

Moreover, smoke and temperature sensors are installed in the bathroom and pantry, with their addresses and locations displayed on the fire detection control module screen, like all other smoke detectors onboard. The fire detection system has been approved by the classification society, as evidenced by the attached certificates (Attachment 6).

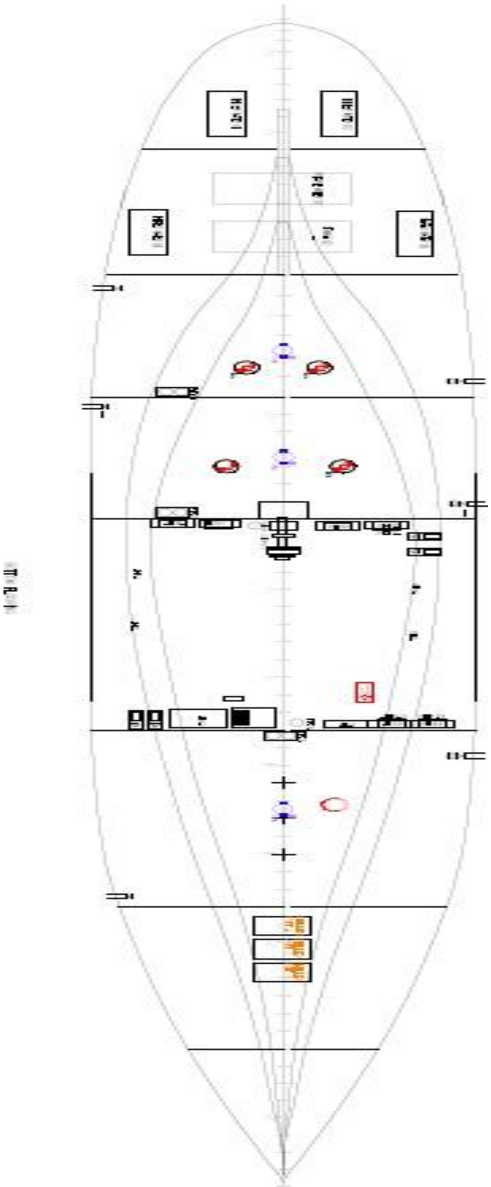

Figure 25 - Fire detection system layout

5 Discussion

5.1 Economic aspects of the project

We can say that the project cost is **roughly** divided as follows (VAT and taxes included):
Vessel Retrofit: ~ 2.5 Mio CHF
Shipyard charge system: ~265’000 CHF
Main Pier: ~1.7 Mio CHF
Documentation for Klik, Myclimate, Planair, EDP etc: ~70’000 CHF

Is important to say that this project was possible only with financial aid from UFT and Ufficio federale dell'ambiente (UFAM), a guaranteed total of 1’341’236 CHF.

6 Conclusions and recommendations

The SNL project has proven to be a resounding success, particularly in terms of the vessel's remarkable reliability and the efficiency of its charging infrastructure. However, it wasn't without its challenges, especially during the initial phases. One major hurdle encountered pertained to the MNE Ceresio's fire system and financing for the project. Given the novelty and ambition of the project, SNL faced difficulties in sourcing appropriately sized equipment with the requisite certifications for professional use, as opposed to recreational purposes. Furthermore, unforeseen delays arose due to the COVID-19 pandemic, exacerbating these challenges. Additionally, the vessel's prior condition, marked by corrosion in several areas, demanded extensive re-treatment, further prolonging the project timeline. Notably, the presence of a wooden floor on the main deck necessitated its replacement with A60 panels, adding to the complexity of the retrofit. In terms of supplier selection, SNL initially considered numerous competitors vying for the project, and ultimately Baumüller was chosen for their ability to tailor a bespoke solution rather than offer off-the-shelf products. Their flexibility allowed for the adaptation of motor dimensions to suit the vessel's requirements, facilitating the seamless integration of equipment on board. Despite this success, the economic aspect posed its own set of challenges, as budgeting for such a pioneering project proved to be a dynamic process. SNL had to adjust spending multiple times to accommodate unforeseen expenses associated with the MNE Ceresio retrofit. Looking ahead, SNL recommends initiating dialogue with authorities and field experts from the project's outset to pre-emptively address potential obstacles. Additionally, gaining a comprehensive understanding of regulatory frameworks and market dynamics concerning spare parts beforehand can mitigate the risk of lengthy delays or the need for extensive system overhauls mid-project. These proactive measures can streamline operations and enhance the overall success of future endeavours.

List of attachments

1. Technical documentation of the fast-charging station cabin
2. UFT certification document from the testing of the MNE Ceresio
3. UFT certification document from the testing of the MNE Ceresio
4. UFT certification document from the testing of the MNE Ceresio
5. UFT certification document from the testing of the MNE Ceresio
6. Fire safety certification
7. Test result reporting for May and June 2025
8. Fast charging procedure manual