VER/FLB 069/10

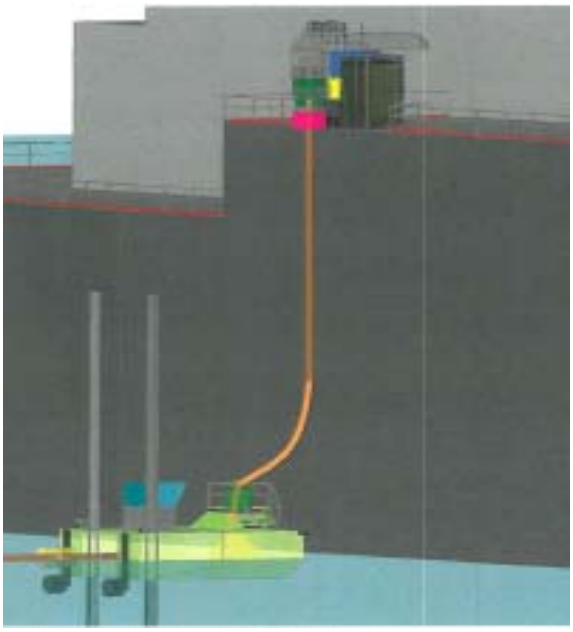
Project no.: **TST5-CT-2006-031477 Power Generation during Loading & Unloading**

Project acronym and title

PLUG

PLUG Final Publishable Report

Deliverable D1



Due date of deliverable: 29 months after Project starting date
Actual submission date: 30 months after Project starting date

Period covered : from October 15, 2007 to March 15, 2009
Date of preparation: April 2009

Final update : June 2010

Start date of project: October 15, 2006
Duration: ~ 2,5 years

Organisation name of lead contractor for this deliverable: **SNECMA**

PUBLISHABLE EXECUTIVE SUMMARY

"PLUG" is a joint research and development effort supported by the European Commission to develop an innovative, high capacity (up to 25 MW) ship-to-shore power interface for the new generation of Dual Fuel Diesel Electric (DF/DE) Liquefied Natural Gas Carriers (LNGCs).

This interface will allow to connect the vessel to the local power grid during harbour operations in order to :

- Either run the ship's diesel generating plant at full capacity (up to 25 MW) and sell power to the grid, while acting as a low emission "shadow" power backup for RES projects,
- Or import power (up to 8 MW) from the grid for hotel and cargo pumps loads to avoid local emissions penalties and use oversupply of local RES capacities.

The project objective is not only to develop and qualify safe and user-friendly operations for the power transfer, but to provide as well an effective software "link to the market" to enable an efficient and speedy / real time (less than 15 minutes) decision making, between the different stake holders (crew, ship owners, charterers, port and state authorities…) to either export or import power between the vessel and the shore.

The Plug Project strengthens and integrates the European Industry and Research Community, by gathering 5 partners from 3 different countries including two SMEs and one research centre, allowing early and practical dissemination of its outputs and offering training opportunities for European researchers and students.

The different partners main roles within this project are the following:

SNECMA (France) : as project coordinator and leader.

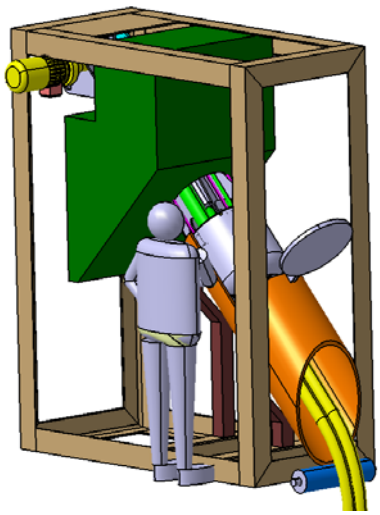
STÄUBLI (France) : high voltage /high power connector technology.

LEDUC (France) : harbour and power line handling technology.

WAVESPEC (United Kingdom) : crew and terminal operation procedures.

CONVERTEAM (France) : electrical architecture.

SINTEF (Norway) : "link to the market " software.



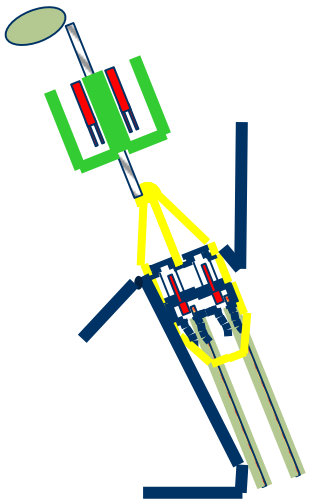
PLUG power interface concept

One of the main design driver for the consortium has been to develop a safe and user-friendly power interface concept, in order to make these power exchange operations acceptable by the shipping community.

Therefore, the main technical objectives were :

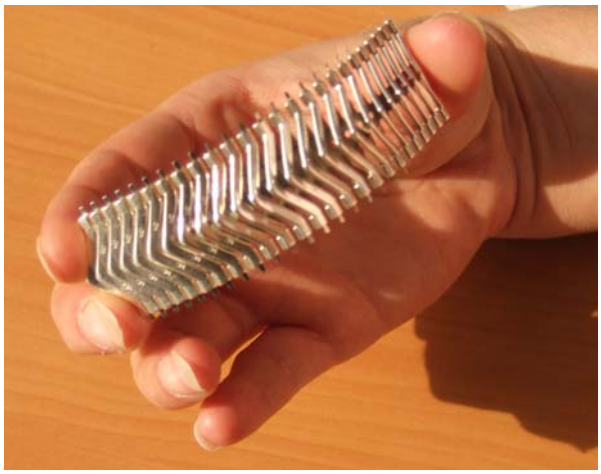
- to have a self connecting /disconnecting power connector, so that no manual handling of the power line is required.
- to have power line operations as simple and fast as the one required for a mooring line.
- to have a safe and remote emergency release capability, in order to meet the safety requirements of LNG carriers and terminals.

Aiming at these objectives, an innovative concept of power interface has been produced, with a single, water proof, self mating / de-mating connector, which is towed towards the vessel power socket by a towing cable, making the power line operations as simple as for a mooring line, allowing safe “hands out” operations with only one crew member and meeting the safe remote emergency release capability requirement.



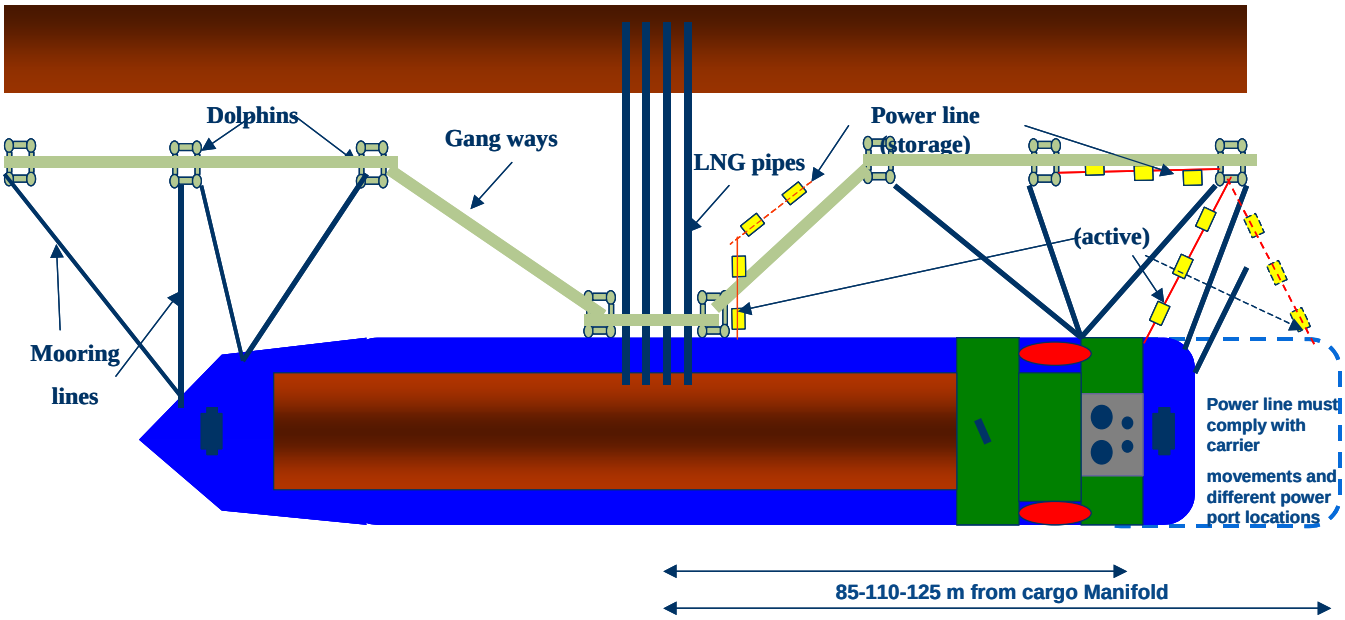
PLUG connector concept

Another key issue which has been success fully solved are the selection of the power contact technology, as well as the detailed concept of the self mating /de-mating connector.



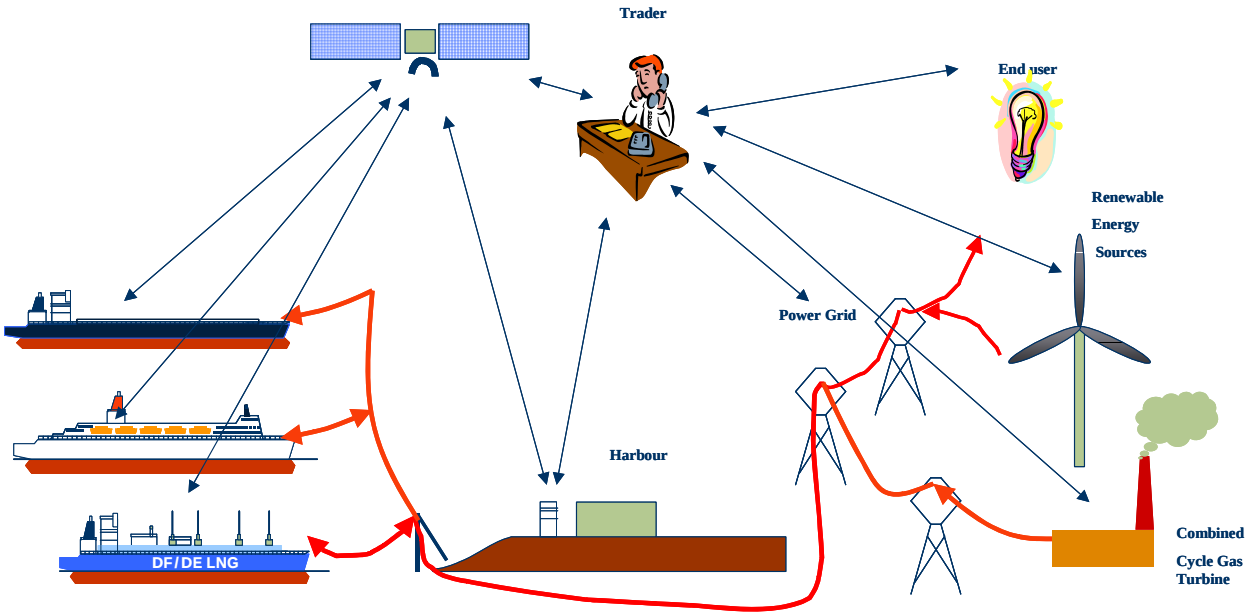
PLUG power contact technology

The operational and safety constraints of LNG carriers an terminal have been investigated with classification societies, ship owners and terminal operators. Different power port locations have been proposed to check which were the most appropriate.



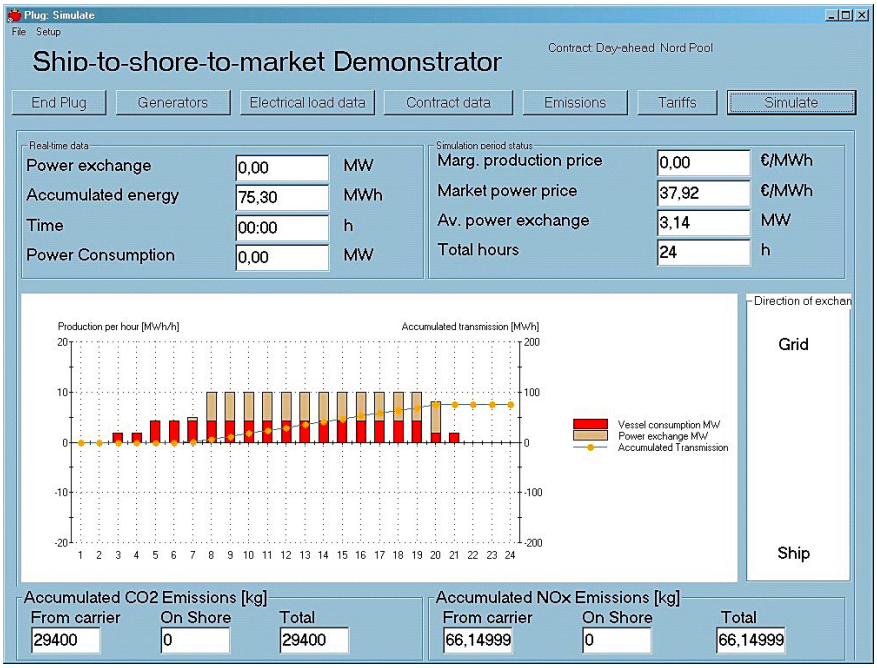
Possible PLUG power line implementation in the case of LNG carriers

In parallel with these connector and power line design activities, numerous dissemination actions have been prepared to present the PLUG concept to the market, showing especially that this concept could be used to achieve a global optimisation of emissions in combination with Renewable Energy Sources (RES).



PLUG global emission optimisation concept

To support this scheme and to address the challenge of having numerous stakeholders quickly reaching an agreement to perform the power exchange in one way or another during the very limited time a vessel is at quay, a specific software development has been initiated to provide an efficient "link to the market ", offering a "quarter-of-an-hour" decision making capability.



PLUG "link to the market "software interface

Confident in the success of the project, the Consortium has already identified potential harbours and shipowners who could be interested to perform PLUG dedicated cases studies, not only on intended LNGCs with full size demontrator tests, but also on other types of vessels (containers carriers, cruise ships, chemical carriers, ferries,…) for which the unique features of the PLUG concept present key operational and/or safety advantages.

Market release for the PLUG concept is expected in 2010 and demonstration testing within the following year.

PLUG Project LOGO

The co-ordinator contact details are:

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Section 1 – Project objectives and major achievements

The main project objectives of the PLUG project are summarized in the following table:

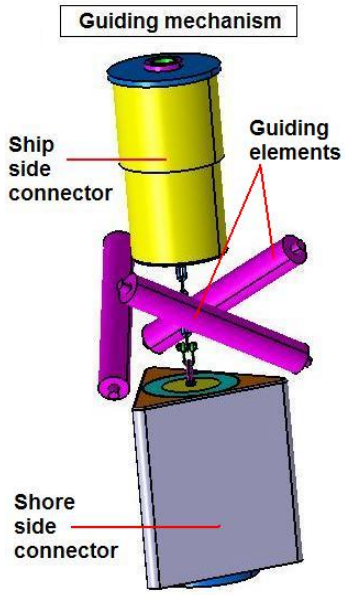
Item	PLUG Objectives
To develop a quick connection	Connection in less than 15 minutes
Emergency release capability	Compatible with current emergency requirements
Versatility	Compatible with 50 /60 Hz power grid Frequency Compatible with existing LNG terminal harbour facilities
Versatile w.r.t vessel size and types	Applicable to LNG, containers carriers, cruise ships…
Capability	Up to 25 MW Capable to exchange power in both directions
Compatible with CTE	Power/fuel measurements fully compatible with Custody Transfer Equipment
Safety	Safe or safer than state of the art power interfaces Compatible with LNG carrier and terminal safety requirement's
Real time capability	Direct interface with power trade quotation system enabling a "quarter of an hour ahead capability"
Competitive	Investment below 1,5 M € for the terminal and 1 M € for the vessel, no extra crew requirement Operations as simple as a for a mooring line

PLUG Objectives

The technologies selected for the PLUG project, in particular the selected technologies and concept of the PLUG connector allow to meet or even exceed all these requirements. Compared to the state of the art, the PLUG concept is a breakthrough with regard to ergonomics and safety.

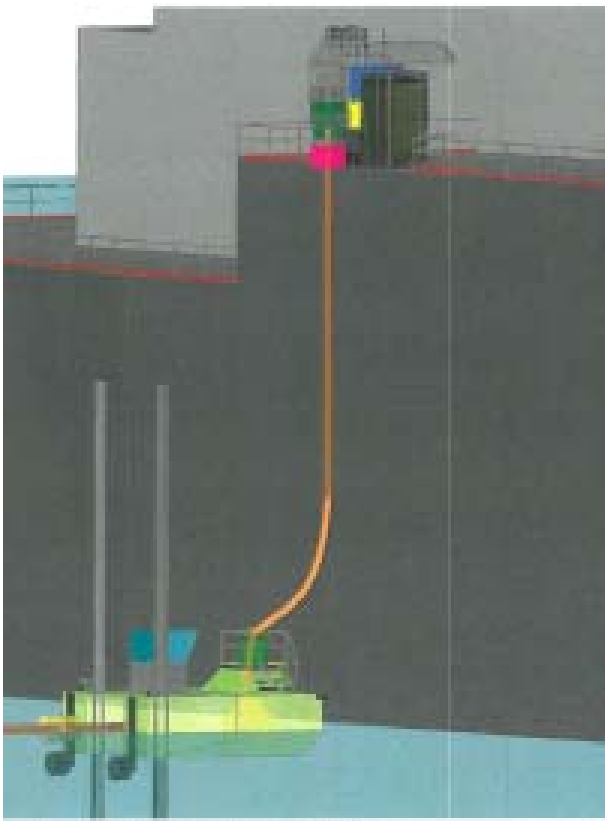
Examples of state of the art cold ironing connections

To meet the PLUG requirements, STÄUBLI developed an innovative high voltage / high power self mating / de-mating connector which allows a single person to tow on board the power line . One of its unique feature is its triangular shape which allows to automatically align the electrical contacts in front of one another.

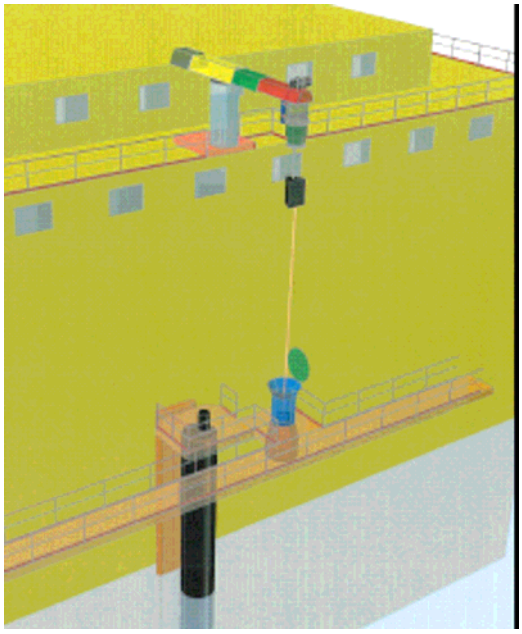


Connector patented concept developed for PLUG

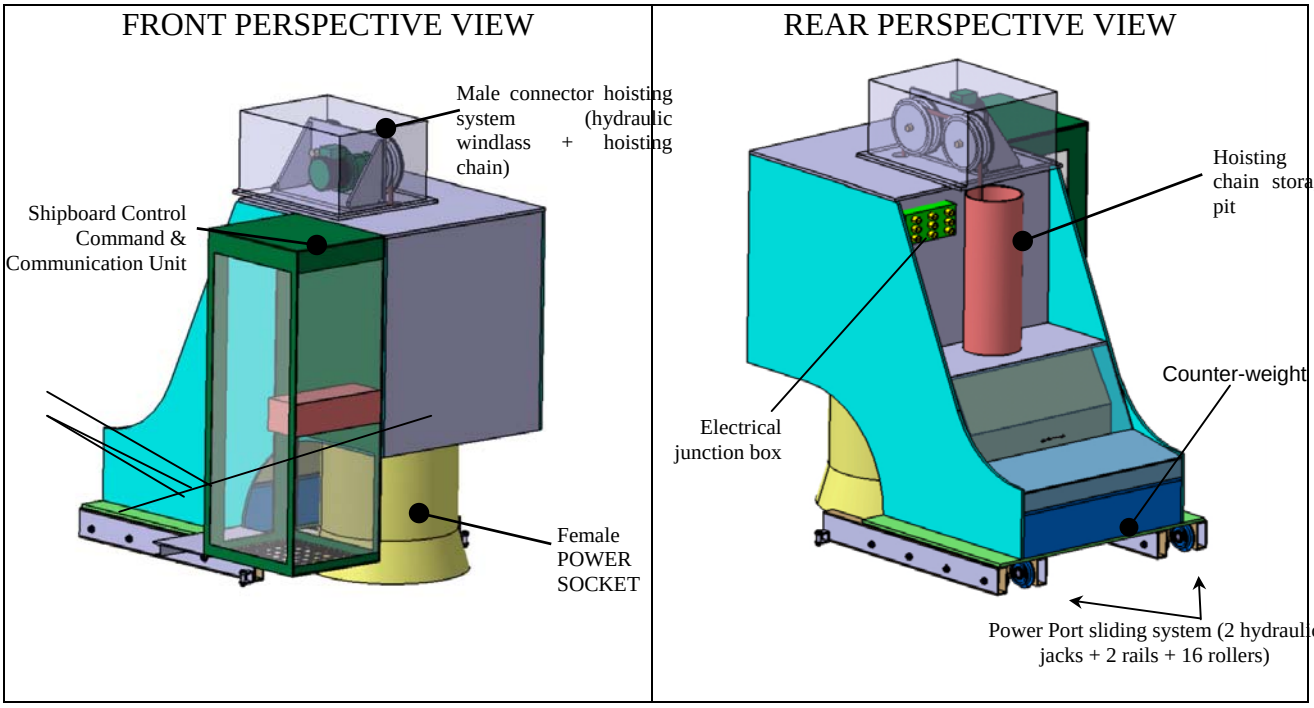
Based on this connector concept, SNECMA with its partners has developed concepts for the “Power Ports “ and “Cable Management System” both in the case of ferries and LNG carriers.



PLUG Power Port and Cable Management System concepts for LNGCs



Power Port and Cable Management System concept for ferry



3D CAD drawings describing one POWER PORT UNIT

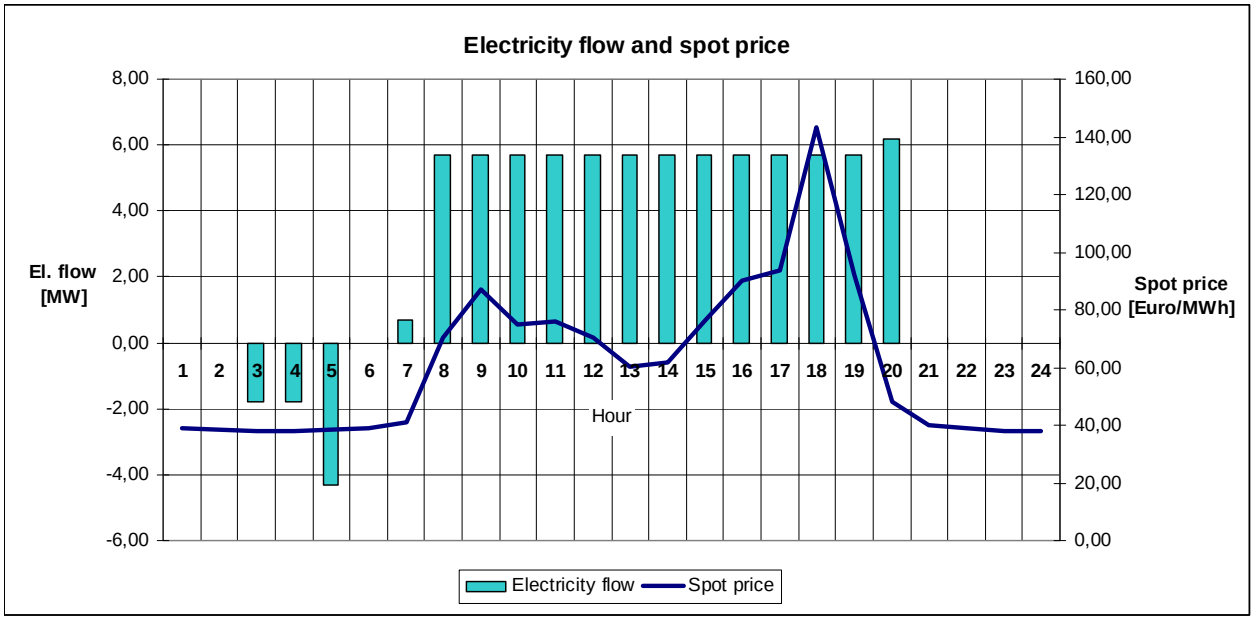
Item	PLUG Objectives	State of the art solutions
To develop a quick connection.	Connection in less than 15 minutes.	> 30 minutes.
Emergency release capability.	Compatible with current emergency requirements.	Not compatible. Only possible with additional mechanical breakers.
Versatility.	Compatible with 50 /60 Hz power grid Frequency Compatible with existing LNG terminal harbour facilities.	Feasible with significant harbour engineering and plant to support and handle the power line.
Versatile w.r.t vessel size and types.	Applicable to LNG, containers carriers, cruise ships, chemical carriers, ferries…	Not applicable to vessels requiring an emergency capability such as LNGCs Not compatible with vessels having a very short stay at quay, such as ferries…
Capability	Up to 25 MW. Capable to exchange power in both directions.	Not considered, but feasible.
Compatible with CTE.	Power/fuel measurements fully compatible with Custody Transfer Equipment.	Not considered, but feasible.
Safety.	Safe, or safer than state-of-the-art power interfaces. Compatible with LNG carrier and terminal safety requirements.	Not compatible with remote emergency release capability. Only possible with additional mechanical breakers.
Real time capability.	Direct interface with power trade quotation system, enabling a "quarter-of-an-hour go-ahead capability".	Not considered, but feasible.
Competitiveness.	Investment below 1,5 M € for the terminal and 1 M € for the vessel. No extra crew requirement. Operations as simple as a for a mooring line.	Significant extra harbour and power line engineering and plant. Larger investment and operating costs expected. Extra crew required. More complex operations.

PLUG Objectives versus state of the art solutions

Beyond the economical benefits, main strategy is to promote the safety benefits and operational reliability that our "PLUG" could bring to "cold ironing" activities, thus giving a reliable and valuable advantage against competition.

(*) Cold ironing is a US navy term for the use of shore power supply to meet power loads on vessels when they are in harbour. In this case, the on board generator sets are switched off and the engine room becomes cold, hence the term "cold ironing".

Based on the inputs from the project's group SINTEF has developed a Ship-Shore power exchange software demonstrator. The work has included assessment of the potential power market products, definition of the most feasible target market products, specification of the requirements and their implementation in the Demonstrator.



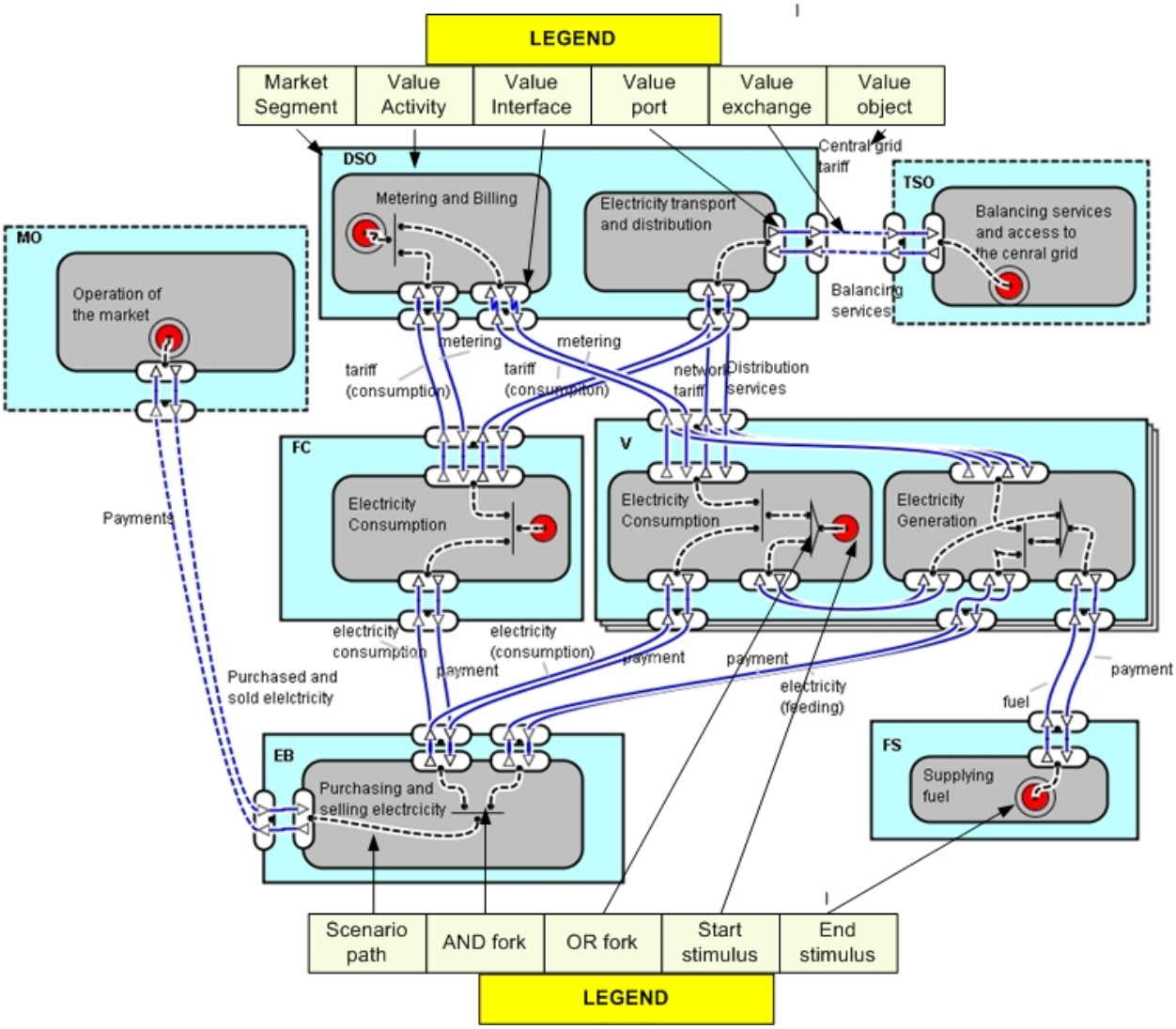
Example of simulation:
Electricity exchange between the spot market and vessel during high spot price volatility period.

The Demonstrator allows simulating electricity exchange between harbour and vessel, based on different pricing models (spot prices, constant prices etc.). In order to disseminate the results, the Demonstrator is available for free downloading from the SINTEF's web-page: (http://www.sintef.no/plug).

SINTEF Energiforskning has mapped the potential markets and the involved actors, which are commercially relevant in the scope of the project. Based on this, a business model for operation of PLUG has been developed. The model is based on e3value business methodology. The methodology has been developed at Free University of Amsterdam by Dr Jaap Gordijn and Prof Hans Akkermans and successfully applied in several European R&D projects. Technical data and specification of expected load profiles related to LNG tankers has been provided by Högh LNG shipping company (Norway) and by WAVESPEC Ltd. It has been chosen to use the LNG installation at Melkøya in Northern Norway as a reference point for the business models and the scenarios. The scope of the study includes the following:

- Evaluation of the contractual and commercial aspects by identifying the relevant segments of deregulated power market and mapping the relevant actors involved in the power trade.
- Development of business models involving electricity distribution network, Renewable Energy Sources (RES) and vessel's production/consumption potential using PLUG connector
- Collection of relevant electricity market data
- Performing of case simulations and evaluation of the impacts

In order to perform the case simulations and assess profitability of the developed business model the study has developed a new version of the Demonstrator, allowing one-year long simulations.



PLUG business model (based on e3value methodology www.e3value.com)

CONCLUSION :

Although the PLUG concept was meeting the project objectives, the Consortium requested to stop the activities before starting the detailed engineering and test of the demonstrator, due to time constraint linked to demonstration project postponement and evolution, requiring market re-assessment and industrial future policy investigations.

It was commonly agreed by Consortium partners to stop the works at the achieved concept level.

Section 2 – Project dissemination and use

Section 2.1 - Exploitable knowledge and its Use

Overview table

Exploitable Knowledge (description)	**Exploitable product(s) or measure(s)**	**Sector(s)** of application	Timetable for commercial use	Patents or other IPR protection	**Owner** & Other Partner(s) involved
Electrical architecture studies report (4MZH0442 D4)	*Drive & control*	*Marine propulsion*	*2009*	*/*	***CONVERTEAM***
Power line and connection electrical specification (4MZH0452 D5)	*Drive & control*	*Marine propulsion*	*2009*	*/*	***CONVERTEAM***
Quick connection electrical constraints (4BZE0233 D6-D7)	*Drive & control*	*Marine propulsion*	*2009*	*/*	***CONVERTEAM***
Cable specification (4MZH0600 D14)	*Drive & control*	*Marine propulsion*	*2009*	*/*	***CONVERTEAM***
120° Self indexing system	*MEP electrical connector product range*	*High Power automatic and safe 3 poles electrical*	*2010*	*Patent application request (not yet published)*	***STÄUBLI***
General Power Line Architecture Preliminary Studies Report	*Ship-Shore connections*	*Marine Cold Ironing Process & Equipment*	*2010*	*Rights & Results transferred to NG2(*) 2010/01/10*	***SNECMA (with LEDUC)***

*Note (*) NG2 : **New Generation Natural Gas**, innovating start-up company created in July 2008 with Headquarters located at 174 Bd Haussmann in 75008 Paris.*

Electrical architecture studies report (4MZH0442 D4) : The aim of this specification is to give a list of material (with functional definition) for the well operating high voltage shore connection switchboard. The furnished material would be defined precisely in particular study for each cases. This Document might be exploited on an individual basis.

Power line and connection electrical specification (4MZH0452 D5) : This specification defines the first technical requirements for the 'quick connection' design. This Document might be exploited on an individual basis.

Quick connection electrical constraints (4BZE0233 D6-D7) : The aim of the study is to define the first electrical constraints of the system. The harmonic signature of the converter drive system along with the harmonic filter sizing calculations will be given. This Document might be exploited on an individual basis.

Cable specification (4MZH0600 D14) : The aim of the document is to specify a sub sea cable doing the link between ship and shore when a ship is docked in order to develop a new power connection. This Document might be exploited indirectly.

120° Self indexing system : The invention relates to a system that performs an automatic indexing at 120° for the simultaneous connection of 3 high power electrical contatcs (up to 25 MW) and presenting the following advantages :

- Full automated connection process (no human hands-on).
- High level of safety in operation.
- High level of robustness (designed for the marine environment).

The invention belongs to STÄUBLI, leader company in the field of quick-release connectors, and will be implementable in STÄUBLI's multi-pole automatic electrical connector product range for similar market requirements.

General Power Line Architecture Preliminary Studies Report : The scope of this document is to provide a common architectural-functional specification for the PLUG supply equipments which consists in :

- One (1) POWER PORT UNIT, as implemented on the ship Starboard side,
- One (1) POWER PORT UNIT, as implemented on the ship Port side,
- One (1) SHIP ACCEPTANCE TEST UNIT, based on outfitting quay side or dry dock,
- One (1) POWER LINE, to establish electrical connection between one Power Port Unit and the Ship Acceptance Test Unit.

The results might be exploited directly by NG2, innovating start-up company to whom they have been transferred on 20th of January 2010.

Section 2.2 – Dissemination of knowledge

Planned or actual date	Type	Event	Type of audience	Country Addressed	Size of Audience	Partner involved
December 2006	Flyers	**Gastech 2006 Exhibition Abu Dhabi**	Natural Gas industry		>5 000	SNECMA WAVESPEC
February 2007	Article	Afrique Asie Magazine	General public	France / North Africa	> 10 000	SNECMA
April 2007	Flyers	**LNG 15 Exhibition Barcelona**	Natural Gas industry	All	>5 000	SNECMA WAVESPEC CONVERTEAM
April 2007	Article	Navire & Marine Marchande magazine	General Public	France	> 10 000	SNECMA
September 2007	**Paper Oral presentation**	**SIGTTO meeting Paris**	Gas and LNG ship owners & shipyards	All	>200	SNECMA, WAVESPEC STÄUBLI
September 2007	Website	PLUG page in SINTEF website	General Public	Norway	?	SINTEF
November 2007	Meeting	**ISO meeting on cold ironing Charleston (SC)**	Ship owners & shipyards ISO committee	All	20	STÄUBLI
November 2007	Website	www.SINTEF.no/ plug	All	All	?	SINTEF
December 2007	Poster presentation	**European Offshore Wind conference Berlin**	Renewable Energy Source Industry and Research	Europe	>1 000	ALL
March 2008	**Paper oral presentation**	**Gastech 2008 Exhibition Bangkok**	Natural Gas industry	All	>5 000	SNECMA CONVERTEAM WAVESPEC
March 2008	Article	LNG World Shipping journal	LNG shipping	All	> 4000	SNECMA
March 2008	Article	Journal of Energy Innovation and Entrepreneurship	All	Primarily USA	?	SINTEF
September 2008	Paper oral presentation	NORDAC 2008	Electric Utilities	All	>100	SINTEF

Section 2.3 – Publishable Results

On the concept side, STÄUBLI has released a 3D video demonstrating the mating concept during the connection process. However, the subject video cannot be published now, since this mating device "120° self indexing system" is under patent application.
No other specific results are publishable since there are no demonstrators in operation;

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