IEEE EPPC Working Group on Energy
IEEE ICA “Sustainable Maritime”

Smart and Sustainable ports

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IEEE Sustainable Maritime: Smart and Sustainable ports

Policy document on smart & sustainable ports (IEEE/EPPC/GPPC)

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- The biggest Technical body of engineers (supporting the science and training),
- 423,000 members,
- 160 countries,
- 150 peer reviewed journals,
- 1,800 conferences/year in 95 countries,
- 1,200 standards (e.g. IEEE 802.11: WiFi, IEEE 45: Shipboard installations, IEC/ISO/IEEE 80005: cold ironing)
Facing New challenges

Fit for 55%
Facing New challenges

• ➔ 55% fit package of directives

Documents released on July 14th, 2021 ➔ maritime related

The set of documents-directives released by the European Commission is enlisted below:

- amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en
- carbon_border_adjustment_mechanism_0
- chapeau_communication
- fueleu_maritime_-_green_european_maritime_space
- notification-carbon-offsetting-and-reduction-scheme-international-aviation-corsia_en
- proposal_for_a_directive_on_energy_efficiency_recast
- proposal-amendment-effort-sharing-regulation-with-annexes_en
- refueleu_aviation_-_sustainable Aviation_fuels
- revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0
- revision_of_the_energy_tax_directive_0
- revision_of_the_eu_emission_trading_system_for_aviation
- revision-eu-ets_with-annex_en_0(1)
- revision-market-stability-reserve_with-annex_en
- revision-regulation-ghg-land-use-forestry_with-annex_en(1)
- social-climate-fund_with-annex_en
- strategic_rollout_plan_support_rapid_deployment_of_alternative_fuels_infrastructure
Facing New challenges

Fit for 55% Maritime sector related

Mandate
AFIR+FuelEuMaritime (09/2023): electric interconnection of ships in ports 1/1/2030

Electrification is considered as the ultimate alternative towards green shipping
Facing New challenges in ports

Smart & sustainable

Electrification

Viable, Profitable, Long-lasting,…
The starting point: Electric power interconnection between ships and shore
Port Electrification

Shore side electricity (cold ironing)

Deployment in ports

Charging of electric (battery powered) ships
Standardization of shore-to-ship interconnection

List of standards related to 80005 series

IEC 60034 Rotating machinery
IEC 60090-151-2001 Electrotechnical Vocabulary
IEC 60076 Power transformers IEC
60079 Explosive atmospheres
IEC 60092-101 Electrical Installations in ships

IEC 60092-201 Ship System Design
IEC 60092-301 Ship Equipment
IEC 60092-503 Ship special features
IEC 60092-504 Automation Control & Instrumentation
IEC 60146-11-2000 Static Frequency converters
IEC 60332-1-2 Tests on electric and optical fibre cables under fire conditions
IEC 60364-4-41 LV electrical Installations

Amendments of IEC 80005-1,-3,-4 (DC)

IEC 60502-2 Power cables
IEC 60947-5-1 Low voltage switchgear
IEC 61363-1 Procedures for calculating short-circuit currents
IEC 61936-1 Power installations exceeding 1 kV ac
IEC 62271-200 High voltage switchgear and control-gear
IEC 62613-2 Plugs-sockets, outlets and ship couplers for high voltage shore connection systems

IEEE Recommended Practice for Electrical Installations on Shipboard

IEEE 45.1: Design
IEEE 45.2: Automation & Control
IEEE 45.3: Systems Engineering
IEEE 45.4: Marine Sector & Mission Systems
IEEE 45.5: Safety Considerations
IEEE 45.6: Electrical Testing
IEEE 45.7: AC Switchboards
IEEE 45.8: Cable Systems
Current status of electric Grids
Increased demands for green electric energy
Port Electrification

ROADMAP TOWARDS SMART PORTS

- EU
- Member State
- IMO

- Load Forecast of ports
  - Core
  - Comprehensive
  - Other

- Grid Expansion Planning
- RAE
- TSO
- DSO
- Studies I

- Port Energy transformation
  - OPS
  - RES
  - ESS
  - EMS

- Implementation
- Studies II
- Port
- Grid

- Preparation for operation
  - Port business model
  - Studies III
1. EU fit-for-55% (2030→2050)+ 2017/352/EU+2019/944/EU
3. Estimation of peak power demands of ports (load forecasting)
4. Accurate load forecasting of ports (case by case, all loads included)
   1. Core ports
   2. Ports of the comprehensive network
   3. Other ports
      1. Mainland
      2. Islands (electrically interconnected)
      3. Islands (electrically non-interconnected)
5. Grid expansion planning
   1. DSO (5-year development plan)
      1. Technical issues - phase 1: planning+design
      2. Regulatory issues (?)
   2. TSO (10-year development plan)
6. Port energy transformation
   1. OPS planning
   2. Energy transformation planning
7. Implementation
   1. Grid expansion
   2. Port infrastructure procurement + installation
   3. Investigation of technical issues - phase 2: before the operation
   4. Commissioning and testing
8. Preparation for Operation
   1. Establishment of port business model (energy market)
   2. Investigation of technical issues
   3. Training
   4. Operation

Analysis of Roadmap
## Following the Roadmap - Further Challenges

1. **Planning** Grid expansion
   1. Future Peak Power and energy demands
   2. Stability issues (frequency, voltage)
   3. Power quality (e.g. harmonic distortion, EMT-transients)
   4. Resilience
   5. Deployment of RES+batteries

2. SSE ship ID
3. SSE port ID

4. **Power Quality** problems
   1. Harmonic distortion
      1. Frequency converters
      2. LEDs
      3. Cranes
   2. Inrush and sympathetic inrush
      1. Isolation transformer(s) energization
      2. Centralized configuration of frequency converters + many isolation transformers in parallel
   3. Earthing, protection, equipotential bonding issues, corrosion

5. DC and inductive charging
6. **Port demand management + flexibility**
   1. Load shedding,
   2. Operation in economy mode: exploitation of RES, ESS
7. **Ship demand management** (load shedding, economy mode)
8. Operating models of ports and ships in the electric market
9. Regulatory issues, pricing policy, tax exemptions
10. Re-cycling policy (esp. batteries)
11. Training and Education (port electrical engineering)

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**The port networks must be (in brief)**

- Robust,
- Resilient,
- Reliable and
- Flexible

**The port must**

- > help the energy supply chain
- > Comply with energy market
Holistic Energy Upgrade of Ports

- Cold Ironing (Ship-to-Shore interconnection):
  - Ports in Europe (projects: ELEMED, EALING, CIPORT, ALFION)
- Charging of battery based electric/hybrid waterborne vessels
- Energy storage (buffering, swapping)
- RES deployment
- Electric Vehicle charging stations
- Reefer power supply
- Smart LED Lighting
- Regenerative crane braking
- Energy management system
- Further steps
Holistic Energy Upgrade of Ports

Towards smart green ports

- Long-term contracts
- Short-term agreements
- Emission trading
- Subsidies/discounts
- Smart energy management for reefers
- Regenerative crane braking
- Estimation of RES potential
- Parking under P/V
- Storage
- Battery swapping for electric vessels
- Electric cars

The Proteus Plan

- Energy management
- Operation monitoring
- Fault identification
- Environmental Protection
- Cost reduction - Service quality
- Energy pricing
- Cheap energy purchase
- RES energy storage
- Peak shaving
- Smart lighting
- Remote control/monitoring
- Lifi
- Estimation of RES potential
- Surface covering
- Estimation of RES potential
- Surface covering
- IEC 80005-1/2/3
- Capacity increase/redundancy
- Long-term contracts
- Short-term agreements
- Emission trading
- Subsidies/discounts
- Smart energy management for reefers
- Regenerative crane braking
- Estimation of RES potential
- Parking under P/V
- Storage
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• Energy management
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• Electric cars

The Proteus Plan
The smart & sustainable port

- Ship-to-shore interconnection (cold ironing)
- Smart grids of fairly large power capacity (flexibility)
  - Charging battery based ships with electric propulsion
  - Electric **vehicle charging** stations
  - Interconnect off-shore or near-shore RES
  - **Reverse cold ironing** by green ships
  - Storage for peak shaving & saving excesses of power and/or **battery swapping** or **cloud storage** (sharing electric energy storage capacity in win-win schemes)
  - Sophisticated **Energy Management Systems** ➔ sustainable port Grids
  - Participation in the Energy Market
Deployment of PV’s and small scale wind generator in port areas

PV installation in P.o.L.A. (USA)
Utilization of Energy Storage Systems at the port area

ESS can be used to store **off-peak energy** from the Grid, or energy from Renewable Sources or energy recovered from Cranes. [Energy buffering]

Energy Storage is a significant feature in designing a port’s energy management system that can give the opportunity to the port to participate in the energy market.

Not only Li-ion but **flow batteries** (e.g. VRB’s) too

Support to ships based on batteries [Battery swapping]
The smart & sustainable port

Extending Smart – grids concept

Energy buffering
Battery swapping

Flow Batteries + Cold Ironed Ships

Pillars of the project

- Swappable containerized waterborne transport Li-Ion battery
- EaaS (Energy as a Service) Platform
The smart & sustainable port

Future steps: following the steps of the evolution in computer systems

Cloud computing

Cloud data storage

Cloud energy storage
A ship at berth can offer her storing capacity to the Grid via the port.
The smart & sustainable port

Combination of parking/charging stations for EV’s and PV’s

- Parking/charging under P/V
- Storage

Electric Vehicles of the ports
Reefers have significant thermal inertia. When switched off they can hold temperature for relatively long time. Energy conservation by Reefers is significant in designing a port’s energy management system.

Small increase of temperature despite the long switching-off time intervals (~1.5°C/9h)
• The introduction of LED technology in ports for dock lighting has been a proven low power consumption alternative.
• Different light colors (hot or cold) are suitable for different applications.
• Attention must be paid on how to off-set the harmonic distortion and the high reactive power demand.
• LED lamp controls can be integrated in a smart lighting system that can optimize the luminance/light efficiency versus the cost of energy.

<table>
<thead>
<tr>
<th>Port of Killini</th>
<th>Energy Consumption of LED lamps (kW)</th>
<th>Energy Consumption of Conventional lamps (kW)</th>
<th>Energy saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Port</td>
<td>160.5</td>
<td>240</td>
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<td>North Port</td>
<td>50.0</td>
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LED Lighting

Communication and Control ➔ Li-Fi

- Multiuser
- Terabit/s
- optical wireless capacity **two orders** of magnitude higher than 5G

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Evolution of speed in data transmission

**Benefits of LiFi**
- Military Grade Security
- Ultra Low Latency
- RF-Free Wireless Communications
- Quality of Connection
- 802.11: Straightforward to integrate
Cranes with regenerative braking can have a significant **energy recovery** factor.

Operating profile (two full cycles of operation) of **one** single port crane.
A Port Power Management System (P-PMS) can improve the overall efficiency of the system since it comprises multiple functionalities & features (SCADA):

- Electric Network Monitoring – Protection & Control
- Power Generation Management
- Shore to Ship connection Management
- Energy Storage Management
- Billing System
- Asset Management & Work Force Management
- Incident Management
- Automatic Meter Reading
- Energy Meter Data Management
- Water & Gas Meter Data Management
- Lighting Control & Monitoring
- EV Charging Management
The smart & sustainable port

Maritime electricity market

Electricity Suppliers
- Electricity Supplier 1
- Electricity Supplier 2
- Electricity Supplier N

National Grid (TS,DS)

Port Grid

Aggregator(s)
- Active Customer 1
- Active Customer 2
- Active Customer 3

Operating Schemes

Smart metering

Port Energy Source Aggregator
To step further…

More standards??

- DC interconnection
- Power quality (distortion, inrush, sympathetic inrush load shedding/switching transients)
- Earthing in ports
- Corrosion in ports
- Smart grids + special type distribution networks of large power capacity
- Grid forming power converters with active front ends enabling bidirectional energy transactions + virtual inertia
- Zonal distribution networks in ports
- Smart lighting standards
- Li-fi standards
To step further....
Training/Education

Training – Port electrical engineering

- CPD programs
- MSc Program

- Fundamental environmental issues
- Power Transformers
- Rotating machinery
- Power converters
- Synchronization & parallel operation
- Power quality
- Protection
- Earthing
- High Voltage technology
- RES (PV’s)
- Batteries
- Smart grids
The smart & sustainable port

To step further....
Training/Education

Continuing Professional Development (CPD)

Maritime Electrification
Case study: Port of Igoumenitsa (OLIG s.a.)
ALFION
Alternative Fuel Implementation in IgOumenitsa Port

CEF-Transport-2019 – General Envelope» funding studies (up to FEED) for:

- **OPS/SSE** (cold ironing)
- **Battery swapping**
- **Electric vehicle charging stations**
- **Energy storage systems**
- **Energy management system platform**
Main Connections of the port of Igoumenitsa + ....

Series of possible synergies with Italian ports and other ports in the Mediterranean
➢ Cultivate further the maritime interconnections
➢ Establish a common regulatory framework and tariff policy
➢ Reinforce further the electric power interconnection and the energy transactions
ACKNOWLEDGMENTS

The European Climate Infrastructure and Environment Executive Agency (CINEA) for funding the projects

(CIPORT: Cold Ironing in the Port of Piraeus - Taking the Final step)

(CENTAVROS: Connectivity Infrastructure Upgrade and Environmental Viability for the Port of Volos)

(ALFIOn: Alternative Fuel implementation in Igoumenitsa port)

(EALING: European flagship Action for cold ironing in ports)

(ELEMED: Electrifying the Eastern Mediterranean Corridor)

Acknowledge the contributions from discussions and collaboration
To probe further

IEEE Electrification Magazine special issue (March 2023): *Smart ports*

Upcoming Related events – Support info

- **Roundtable**
  
  “*Operating models of ports and ships in the open electric market*"

*Invited panelists from DGENER and DGMOVE, (Eurelectric, ACER, NTSO-e, EU-DSO)*

- **Webinar**
  
  “*Means of sustainable electrification of ships and ports in view of decarbonisation*”.

Ongoing Amendments of IEC 80005-1,-3,-4 (DC), IEEE 45.1, 45.2, 45.7 (+DC) ➔ 2023

Improvement of MRV-Thetis: collecting data of demands at berth
Electricity is the sole alternative fuel with a plethora of readily available standards, rules, guidelines, know-how on planning, design, operation, control. We must help it succeed.
Thank you very much for your interest

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