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DEFKALION

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πράξη **ΘΑΛΗΣ-ΕΜΠ**, πράξη ένταξης 11012/9.7.2012,
MIS: 380164, Κωδ.ΕΔΕΙΛ/ΕΜΠ: 68/1129

«Investigation of power quality issues in ship electric energy systems» (DEFKALION)
THALIS-NTUA, Approval Decision 11012/9.7.2012,
MIS: 380164, Project registration No of NTUA Research Committee: 68/1129

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DEFKALION

Deliverable:D10.2p
Report of Final Evaluation

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Report of Final Evaluation

This is the report produced by the Evaluation Committee of the THALIS-DEFKALION project (MIS:380164) that convened in the interval 28-29 May 2015. The Committee attended the progress meeting of the DEFKALION team, where the progress of the main work-packages was presented. They also attended the evening event organized in Piraeus, where the interim results were presented to the open public (local maritime community and other stakeholders). This report is split into two parts. In the first section, the Committee provides their remarks on the accomplishment of the specific targets as prescribed in the THALIS project call and the corresponding acts of approvals. In the second section, the Committee provides their remarks regarding the progress attained so far and some recommendations for the project final steps.

1. Contractual part (comments on the composition of the research team)

The Committee re-confirms that, as described in the Interim Evaluation report (Deliverable D10.1), the research team composition fulfills the project specific targets prescribed in the THALIS framework. More specifically:

Multi-University and inter-departmental research team:

16 Academics take part in the Main Research team coming from different Academic Institutions in Greece, namely:

a) National Technical University of Athens (two departments: School of Naval Architecture and Marine Engineering/S-NAME, School of Electrical and Computer Engineering/S-ECE)

- John Prousalidis (Associate Professor at S-NAME),
- Emmanouil Samouelidis (Professor at S-NAME),
- Gerassimos Politis (Professor at S-NAME),
- Christos Frangopoulos (Professor at S-NAME)
- Lambros Kaiktsis (Associate Professor at S-NAME)

- Christos Papadopoulos (Assistant Professor at S-NAME)
- Ioannis Stathopoulos (Professor at S-ECE)
- Antonios Kladas (Professor at S-ECE)
- Ioannis Gonos (Lecturer at S-ECE)

b) University of Patras: Department of Electrical and Computer Engineering (D-ECE)

- Emmanouil Tatakis (Professor at D-ECE)
- Eleftheria Pyrgioti (Assistant Professor at D-ECE)

c) Technical University of Crete: Department of Production Engineering and Management (D-PEM)

- Fotios Kanellos, (Lecturer at D-PEM)

d) Democritus University of Thrace : Department of Electrical and Computer Engineering (D-ECE)

- Nikos Papanikolaou (Assistant Professor at D-ECE)

e) Technical Educational Institute of Thessalia: Department of Electrical Engineering (D-EE)

- Marios Moschakis *(Assistant Professor at D-EE)*

f) Technical Educational Institute of Eastern Macedonia and Thrace: Department of Electrical Engineering (D-EE)

- Dr John Dermentzoglou (Assistant professor at D-EE)

g) Hellenic Naval Academy:

- Georgios Tsekouras *(Assistant Professor at D-ECE)*

Inter-Disciplinary research: researchers from the following disciplines have been engaged:

- Marine engineering
- Naval Architecture
- Electrical and Power Systems Engineering
- Control Engineering
- Mechanical Engineering

Invited Researcher: Professor Sakis Meliopoulos (Georgia Institute of Technology, School of Electrical and Computer Engineering, USA)

2.Technical part

Notes & Comments on WP2 (about shaft generator systems)

The case study looked at a Ro-Ro Ferry with a Power Take Off (PTO) generator system. The work comprised mainly the comparison of two different configurations one with Permanent magnet synchronous generator and another one with salient pole synchronous generator.

The work was well received by the panel and they were happy with the progress and considered it almost complete as per schedule.

The panel commented on:

- the applicability to lower shaft speeds typically found on other types of ships.
- practical design considerations such as volume and mass should also be appreciated.
- The possibilities of the combination of PTI with waste heat recovery.
- The presence of 3rd harmonics between the generator and the conversion equipment is beneficial for 100% protection of the generator. There should not be attempts to minimize the third harmonic. This does not affect the power quality improvements in the distribution system of the ship.

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- The integration of these systems to both 50 and 60 Hz power systems could be investigated.

Answering Notes by the Research Team

The Research took into consideration the comments and suggestions made by the Evaluation Committee. The following notes have been made in the interval between the interim and final evaluation:

a. Few other ship types (e.g. old container ships) also exist with a PTI installed. Ship designers and ship owners have restarted considering of PTI in few new builds. Thus, it is expected that experience gained in this project via the considered ro-ro ferry (the ship grid of which covers several case studies of other ships, too) will be exploited in the near future towards the optimization of the generators installed onboard.

b. Indeed, the research team made the effort to focus on small sized configurations. To this end, the most appealing alternative that was investigated comprised a permanent magnet synchronous motor, i.e. one of the smallest and most efficient electric motors.

c. Considering that in the framework of another project (acronym "ECOMARINE" a waste heat recovery unit based on TEG technology has been developed and constructed a mutual exploitation of results and conclusions is planned to take place.

d. The remark is well noted and since the 3rd harmonic is beneficial no special effort to reduce is to take place.

e. This remark can be easily answered affirmatively considering that both frequencies are met depending on the ship type and its mission, while power converters can integrate the shaft generator systems to either operating frequency

WP2 is considered concluded since the end of 2014. Still the remarks made will be taken into account to the maximum possible extent especially in the final report

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

Notes & Comments on WP3 (thrusters)

The first stage was the data collection of such systems. The second stage was a hydro-dynamic study of the transient torque demand of a CPP thruster. The third stage comprised the design of the thruster electric motor and its associated power interface, the modeling of this system, and the analysis of the power quality of it during the transient start-up phase. The panel is happy with the good progress.

The panel commented on:

- In future projects it would be good if there is an advanced control mechanism for pitch angle change rate for the CPP and motor load/ overload behaviour
- The case studied is an ideal one (i.e. starting-up begins at zero blade pitch angle). Extra overloads are experienced during start up, for example when the bow thruster is a solid pitch bladed propeller, or a piece of wood or rope or other obstacles are present inside the tunnel thus impeding motion.
- In future work, the way to integrate this into a dynamic positioning system could be developed.

The impact of the thruster into the entire system in the light of energy storage devices needs to be considered.

Answering Notes by the Research Team

WP3 is considered concluded.

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

Notes & Comments on WP4

The first stage was the data collection of such systems. The second stage was a hydro-dynamic study of the transient torque demand of a azimuth propulsor. The third stage comprised the design of the azipod electric motor and its associated power interface, the modeling of this system, and the analysis of the power quality of it during the operation phase. The panel is happy with the good progress.

The panel commented on:

- The impact of the airgap on the motor efficiency could be investigated but also considering practical issues such as shock loading which requires a larger airgap.
- The cooling system could be considered in the optimizing design procedure.
- The efficiency and motor diameter (pods size and hydrodynamic performance) should be included in the optimizing design procedure.

Answering Notes by the Research Team

a. The air-gap is a crucial parameter in electrical machine optimization procedure while the selected value is compatible with the manufacturing practices for this class of problems. However, in order to evaluate a larger air-gap impact on the motor efficiency, in order to overcome potential reliability problems due shock loadings, as suggested, an additional investigation has been scheduled for an enlarged air-gap case.

b. The motor cooling is facilitated with respect to standard motor applications due to the machine hosting in the pod area and the cooling system consideration is not expected to considerably affect the motor design issues. It may be noted that the permanent magnet rotor adopted requires very limited cooling, while the stator winding cooling can be ensured by selecting convenient insulation by thermally conducting epoxies, following the current manufacturing trends, enabling to form thermal bridges to the motor casing easily cooled in the considered application. Following the suggestion, a thermal analysis of the motor has been scheduled in order to illustrate the proposed cooling system suitability.

c. An additional analysis has been scheduled in order to adapt the proposed motor diameter and efficiency with the considered hydrodynamic system configuration and performance.

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

Notes & Comments on WP5 (earthing) and WP6 (protection against lightning)

Due to the interconnected nature of these two work-packages it was sensible to combine them. The panel is happy with the good progress and also observed the demonstration (in the School of Electrical and Computer Engineering of NTUA) of the lightning experiments on a ship model.

The panel commented on:

- The material data should be confirmed (it is carbon steel that is used rather than stainless steel; aluminium is used in high speed weight critical crafts such as high-speed ferries)
- The effect of water salinity could be investigated (the difference between sailing in fresh and sea water will be highlighted)
- Understanding the risk to people from lightning strikes would be a useful output to inform policy decisions about safety of personnel.
- Gathering the evidence that ships have actually been hit by lightning strikes would be very useful.

- It is a challenge to investigate what happens in case the ship is nearby land; a better understanding of the difference of potentials (if any) is required to answer this question.

- The assumptions need be clearly stated. For example, the conditions are different between real life (winds, rains, wet decks) and the lab experiment.

Answering Notes by the Research Team

a. The carbon steel material used for the hull construction has been identified and the corresponding parameters (conductivity, permeability etc) have been taken into consideration in all studies performed.

b. The effect of water salinity has been investigated to some extent during the experiments, see for instance Figure WP6_18. It is definitely a parameter that affects the phenomena developed.

c. A guide with a brief set of instructions has been synthesized (see Appendix A).

d. The recorded evidence of lightning strikes on ships are limited. Still, some statistical data and some photos have been collected (see Appendix A and Appendix B, respectively).

e. Investigating the phenomena when the ship is hit being nearby the land is really an interesting challenge. The research team will go on with this investigation in the near future.

f. The assumptions made during the lab experiments follow.

In the experimental setup, the grounded metallic plate where the model is placed on simulates the sea surface which acts as the ground level during a lightning strike. The presence of a water tank simulating the sea volume would be necessary only when investigating the next stage of the phenomenon, directly after the interception of the strike i.e. the dissipation of the lightning current in sea water. As reported in literature in relevant experiments on lightning protection, a high voltage rod represents the downward lightning leader. In these experiments, interception represents only the final stage in the process of natural lightning flash where the downward leader corona streamers meet the upward connecting discharge. Therefore, the presence of clouds which generate the primary stages of a lightning process is not considered in these measurements. Moreover, the actual weather conditions during a thunderstorm such as wind and rain do not affect this final stage of the physical procedure of lightning interception which is dominated by geometrical factors. A wet deck would make the distribution of surface current easier, while a member

of the crew touching a wet metallic object would experience a higher and more dangerous touch voltage. In future, this could be incorporated in the electromagnetic simulations as a "water coating" over the naval steel hull.

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

Notes & Comments on WP7

The panel is happy with the good progress and also observed the demonstration of unbalanced (1-phase) and balanced (3-phase) faults emulated in a ship electric grid emulator (in the premises of the School Naval Architecture and Marine Engineering of NTUA).

Answering Notes by the Research Team

The Research Team will keep focused on enriching the data base created with recordings of power quality events occurring either onboard real ships or the ship grid emulator of NTUA.

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

Notes & Comments on WP9 (dissemination of results)

The panel realizes that a significant number of papers has been presented in conferences and workshops. The panel encourages the research team to publish their work in journals.

Answering Notes by the Research Team

As mentioned above, in the meantime 2 papers have already been published in journals, while 1 more is in the publication queue.Furthermore, more papers are also planned.

Final comments of the Evaluation Committee:

Professor R. Bucknall:

Dr A. Greig:

Mr P. Leontis:

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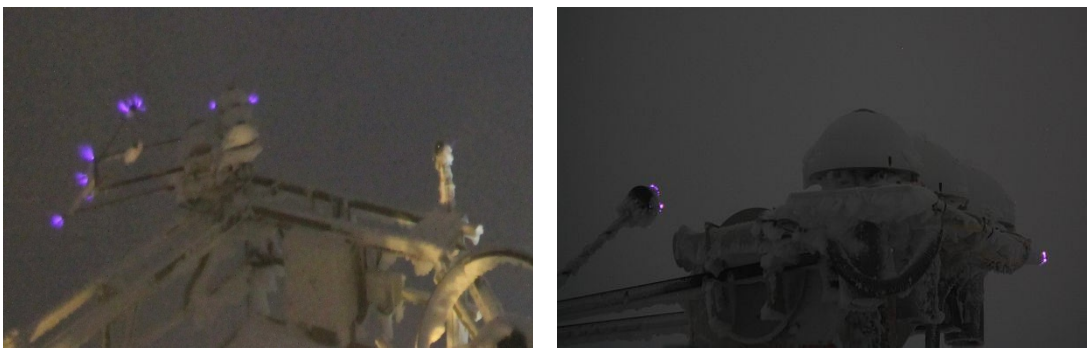
Appendix A

Understanding the lightning strikes – Risks and Protection Measures

The lightning strike is a well known physical phenomenon which is directly related to several failures on electrical equipment and installations. Although significant research has been done on investigating effect of this phenomenon in inland installations and grids, limited relevant work has been done in ship systems. It is noted, though, that sailors can even recognize when their ship is likely to get hit by a thunder by the corona effect (blue or green glows) appearing at the top of the masts



(a) (b)

Photo A.1: St. Elmo's Fire on a meteorological station on Mount Hoher Sonnblick in Austria [3]

The recording of lightning strikes is very rare in the literature. The first systematic attempt is made by the British Royal Navy in the interval 1761-1850, as reported by Bernstein and Reynolds [1]. Furthermore, as cited in [4], Harris had difficulty in persuading his superiors in the British Navy for measures against lightning strikes. He proposed an improved alternative to the chain running from the upper part of the mast downto the deck; he suggested that a copper conductor runs from the mast into the water through the ship hull. One of the first vessels where this means was applied was the "Beagle", the ship through which Darwin travelled. The ship was not destroyed despite the two lightning strikes that hit her during her voyage.

It is only very recently that the whole issue has focused interest again, mainly due to the extensive electrification of most systems onboard. The electrical and electronic equipment is fairly vulnerable to lightning strikes.

It is worthwhile noting that although in land, the probability on an annual basis that a person is hit by a thunder strike is 1/700000 according to the American Meteorological Agency, the corresponding figure onboard a ship changes drastically. More specifically, insurance companies estimate that 1.5 out of 1000 vessels are hit annually by a thunder strike; if interest is focused on sailboats then this increases to 5 out of 1000 [7]. In general every sailboat is anticipated to be hit once in her life cycle by a thunder strike. There is a world record in Florida, where a vessel was hit 5 times in her life cycle; moreover, in the Indian Ocean a vessel was hit twice consecutively (the second strike followed 10 sec after the first) [9].

Related Literature

[1] Ewen M.Thomson, "A critical assessment of the U.S. Code for lightning protection of ships', IEEE Transactions on Electromagnetic Compatibility, Vol.33, No. 2, May , 1991, pp. 132-138.
[2] Wikipedia.org.
[3] https://atoptics.wordpress.com
[4] The Basis of Conventional Lightning Protection Technology, A review of the scientific development of conventional lightning protection technologies and standards, Report of the Federal Interagency Lightning Protection User Group, June 2001
[5] http://www.slate.com/articles/news_and_politics/recycled/2010/06/how_often_do_ships_get_struck_by_lightning.html
[6] Appendix 2_foreign accidents, Request No.: ed_10930, ARIA database, French ministry of ecology, energy, sustainable development and town planning, pollution and risk prevention department sei / barpi.
[7] William J.Becker, "Boating-Lightning Protection", SGEB, Volume 7, October, 1992.
[8] Vincent Daniello, John Clemans, "Lightning-proof your boat", Boatkeeper by motorboating.com, May, 2009, pp.61-64.
[9] Ewen M.Thomson, "Lightning and sailboats", SGEB, Vol. 1, July, 1992, pp.1-23.

General instructions to protect against lightning strikes onboard ships

- Most vessels do not have any **P**rotection **S**ystem **a**gainst **L**ightning (PSaL).
- The Lightning strikes can not be predicted well in advance.
- If a PSaL is installed, then it is highly probable that it can absorb the thunder strike; however, do not be sure that it will always succeed in this.
- If a PSaL is installed, then this must have been protected against corrosion.
- Only a specialized technician can install properly an effective PSaL
- During the storm stay, if possible, in the interior of the vessel.
- In open vessels, stay in the center of it keeping away from you any metallic objects
- No part of your body should not be in contact with the water
- Do not touch two metal surfaces or objects at the same time; otherwise you risk to become the discharging means of the lightning strike
- Do not touch any part of the PSaL of the vessel (the mast of the vessel is amongst the main parts of the PSaL)
- Lower any antennas that are not part of the PSaL
- Disconnect any power cable connections of the electronic devices
- Ask all personnel and passengers underneath the decks and sail towards the land

In case that somebody is hit by a thunder strike:

- Do not panic. Based on statistics, most similar situations have been proven reversible (the brain is not affected up to 20 min after the cease of respiration)
- Proceed to CPR of the victim and call for medical help

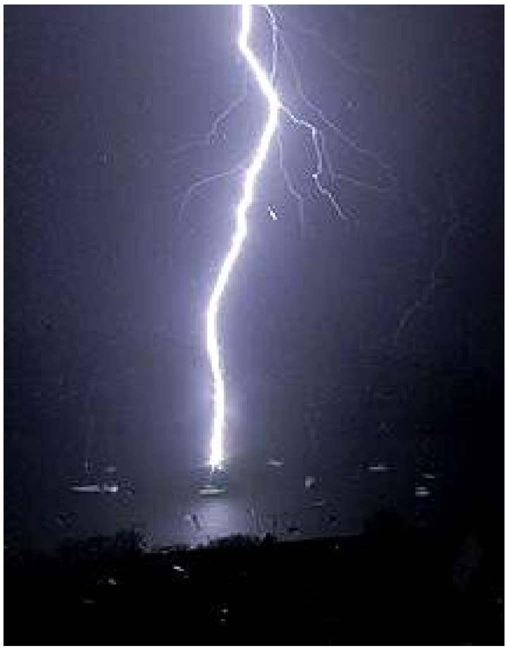
Literature

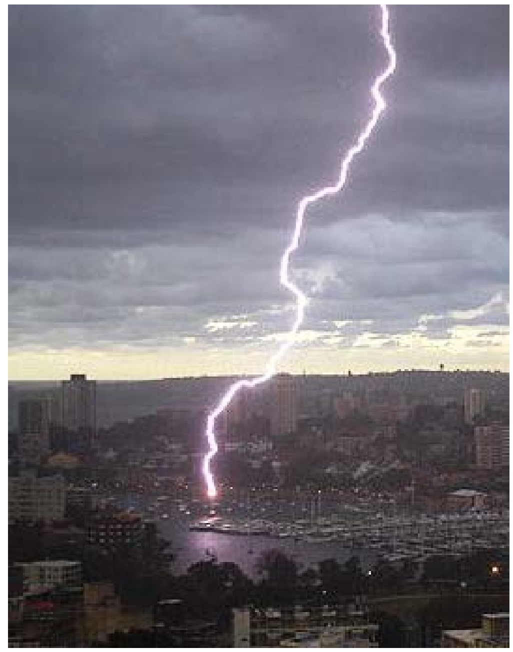
[1] IEC 62305-1,2,3,4,5 *Protection against Lightning* ,
[2] NFPA 780 *Standard for the Installation of Lightning Protection Systems*,
[3] ABYC TE-4 *Lightning Protection*, ABYC E-11 *AC and DC Electrical Systems on Boats*, American Boat & Yacht Council, Inc.

Appendix B

Appendix B

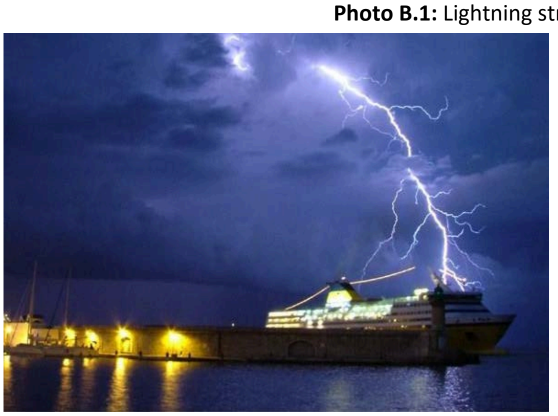
Photos of lightning strikes hitting ships

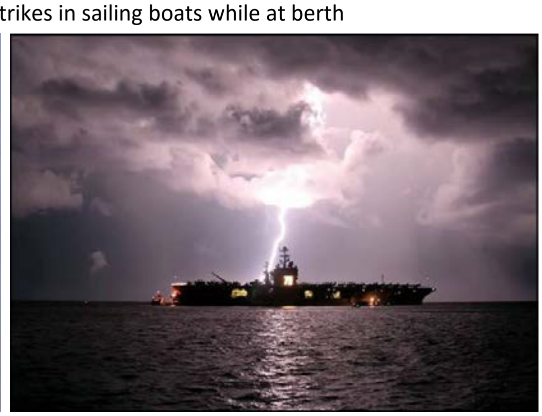




(a) (b)

Photo B.1: Lightning strikes in sailing boats while at berth





(a) (b)

Photo B.2: **(a)** Lightning strike at the highest point of a cruise ship (the immediate black-out is obvious) **(b)** Lightning strike on the super-structure of a war-ship.

Appendix C

Executive summary of Progress Report (submitted to the Evaluation Committee)

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Appendix B

List of publications

List of publications

All publications are part of the Work-package 9 (dissemination of Results). However, in the following list the relation of all publications to each main research work-package is also noted.

List of papers presented in International Conferences/workshops

1. A.Sarigiannidis, C. Patsios, P. Kakosimos, and A. Kladas, "***Control design and performance analysis of shaft generators in ship power systems***", *1st International MARINELIVE Conference on "All Electric Ship",* June 3-5, 2012, Athens, Greece. **[2012-Work-package 2]**
2. A.Pittaras, A. Sarigiannidis, C. Patsios, A. Kladas, J. Prousalidis: "***Design and Comparison of Synchronous Machine Topologies for Application in Ship Shaft Generator Systems***" *Proceedings of 3rd MARINELIVE Workshops on "Prime Movers" – November 21-22, 2012, Athens (Greece),* Paper A2-2. **[2012-Work-package 2]**
3. A. Mountaneas, G. Politis, **Simulation of transient performance of a PODED propulsion, the problem of Grid and motion Generation,** *Proceedings of 5th MARINELIVE Workshops on "Ship Electric Grids" – June 3-4, 2013, Athens (Greece),* Paper B1-1. **[2013-Work-package 4]**
4. E. Chatzinikolaou, C. Patsios, A. Sarigiannidis, A. Kladas, **Exploitation of shaft generators for green efficient ship operation –Electric Machine selection and operation on ship's electrical power system** *Proceedings of 5th MARINELIVE Workshop on "Ship Electric Grids" – June 3-4, 2013, Athens (Greece),* Paper B1-2. **[2013-Work-package 2]**
5. Georgakopoulos, I. Pallis I., E. Tatakis, S. Dallas, **Issues related to the thruster soft starting for all electric ship operation,** *Proceedings of 5th MARINELIVE Workshops on "Ship Electric Grids" – June 3-4, 2013, Athens (Greece),* Paper B1-3. **[2013-Work-package 3].**
6. S.Dallas, A.Skoufis, S. Giannoutsos, A. Charitopoulos, J.Prousalidis: **Establishing a Power Quality Monitoring System onboard,** *Proceedings of 6th MARINELIVE Workshop on "Power Management Systems" – June 4-5, 2013, Athens (Greece),* Paper C2-2. **[2013-Work-package 7]**
7. K. Nikolaou, M. Beniakar, C. Patsios, A. Kladas, *"***Design Considerations in Induction Motors for Ship Thruster Propulsion***", Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper A2-1. **[2014-Work-package 3]**

8. G. Potiriadis, M. Beniakar, A. Kladas, *"Multi-objective Optimization of a Surface Mounted PM Motor for Marine Propulsion Applications", Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper A2-2. **[2014-Work-package 3,4]**
9. S.Dallas, A. Skoufis, A. Charitopoulos, S. Giannoutsos, J. Prousalidis, *"**Analyzing The Electrical Magnitudes Of An On Board Power Quality Monitoring System**" Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B2-5. **[2014-Work-package 7]**
10. J. Dermentzoglou, J. Prousalidis *"***Implementation of Variable Hysteresis Band Current Control Technique in a Ship's Doubly-Fed Induction Machine System***", Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B3-1. **[2014-Work-package 2]**
11. D. Agriostathis, M. Beniakar, A. Kladas, *"***Analytical modeling of eddy current losses in permanent magnet brushless AC machines for marine propulsion applications***" , Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B3-2. **[2014-Work-package 3,4]**
12. J. Pallis, I. Georgakopoulos, E. Tatakis, J. Prousalidis*"**Issues related to propulsion systems fro All Electric Ship Operation**", Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B3-5. **[2013-Work-package 3,4]**
13. T. Mountaneas, G. Politis, *"**Estimating torque demands of electric driven pods and thrusters**", Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B3-6. **[2013-Work-package 3,4]**
14. M Moschakis, F. Kanellos, J. Prousalidis, "**Adapting Smart Grid, RES Penetration, Electromagnetic Compatibility and Energy Efficiency Concepts to Electric Ship Power Systems**", Proceedings of 8th Japanese-Mediterranean Workshop on Applied Electromagnetic Engineering for Magnetic, Superconducting, Multifunctional and Namaterials (JAPMED 2013), June 23-26, 2013, Athens (Greece) , paper No JP8-12. **[2013-Work-package 2,7]**
15. Patsios, M. Beniakar, A. Kladas, J. Prousalidis, "**A simple and efficient parametric design approach for marine electrical machines**", Proceedings of 8th Japanese-Mediterranean Workshop on Applied Electromagnetic Engineering for Magnetic, Superconducting, Multifunctional and Namaterials (JAPMED 2013), June 23-26, 2013 Athens (Greece), paper No JP8-30. **[2013-Work-package 2,3,4]**
16. Patsios, A. Sarigiannidis, A. Kladas, "**Geometry optimization of synchronous machines used on ship shaft generator**", Proceedings of 8th Japanese-Mediterranean Workshop on Applied Electromagnetic Engineering for Magnetic, Superconducting, Multifunctional and Namaterials (JAPMED 2013), June 23-26, 2013 Athens (Greece), paper No JP8-46. **[2013-Work-package 2].**
17. Nikolopoulou, V. Kontargyri, I. Gkonos, G. Tsekouras, E. Pyrgioti, I. Stathopoulos, J. Prousalidis: "**Investigating the Protection of Ship Electric Grids Against Lightning Strikes - The DEFKALION-THALIS project**", *Proceedings of 4th Marinelive workshop on "Ship Automation and Control, November 22-23,2012, Athens (Greece), Paper C1-1.* **[2013-Work-package 6].**
18. G. Peppas, A. Telonis, E. Nicolopoulou, I. Gonos, E. Pyrgioti, I. Stathopoulos: "Simulation of lightning effects on metallic ships", *Proceedings of 6th MARINELIVE Workshop on "Power Management Systems" – June 5-6, 2013, Athens (Greece),* Paper C1-1. **[2013-Work-package 6]**

19. Nicolopoulou E.P., Kontargyri V.T., Gonos I.F., Tsekouras G.J., Pyrgioti E.C., Stathopulos I.A.: "**Experimental application of the similarity theory on scaled strip electrode configurations for the calculation of the grounding impedance**", *Proceedings of the 18th International Symposium on High-Voltage Engineering (ISH 2013), Seoul, South Korea, August 25-30, 2013, paper PB-16, pp. 434-439.* **[2013-Work-package 5,6]**.
20. P. Nicolopoulou, V. T. Kontargyri, I. F. Gonos,G. J. Tsekouras, E. C. Pyrgioti, I. A. Stathopulos, "**Lightning strikes on ships: an initial application of the similarity theory through scaled experiments**", *Proceedings of 2nd MARINELIVE Conference on "All Electric Ship Technology" – February 12-13, 2014, Athens (Greece),* Paper B2-1. **[2014-Work-package 6]**.
21. Nikolaou, M. Beniakar, A. Kladas, "**Design Consideration in Induction Motors for Ship Thruster Propulsion**", *Proceedings of 21st International Conference on Electrical Machines (ICEM 2014), September 2-5, 2014, Berlin (Germany), paper No GD-007897, pp. 2280-2286 .* **[2014-Work-package 3]**
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