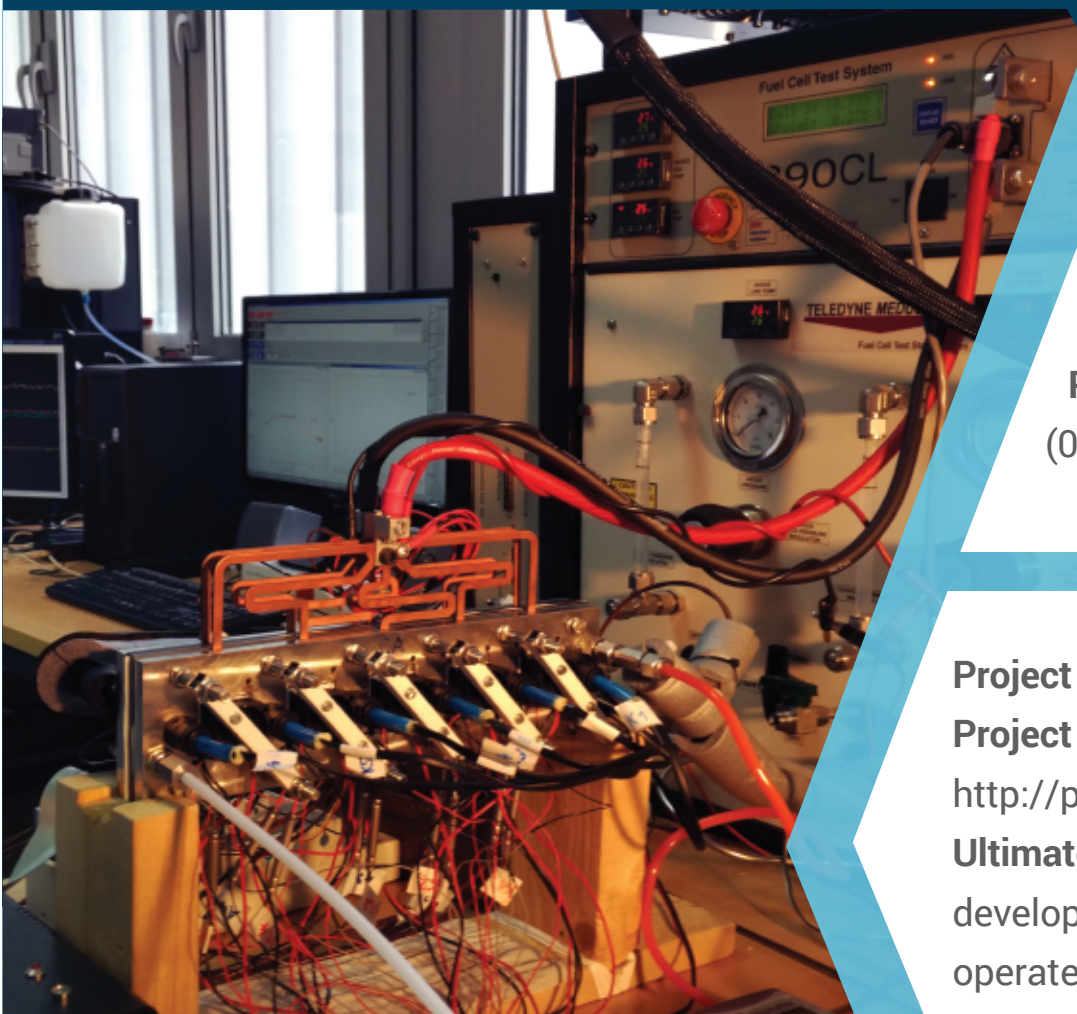


SCIENTIFIC-RESEARCH PROJECT

WATER AND HEAT MANAGEMENT AND DURABILITY OF PEM FUEL CELLS



**Project acronym
(code):** PEMFUELCELL
(IP-11-2013-8700)

Funding: Croatian
Science Foundation (HRZZ)
Project duration: 3.5 years
(01.01.2015.-30.06.2018.)

Project budget: 801,880.00 kn

Project website:

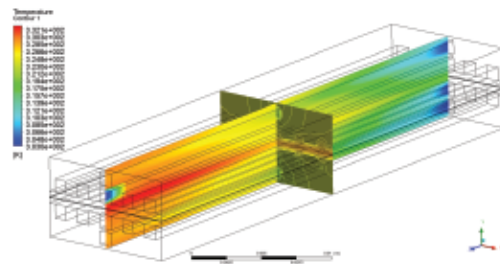
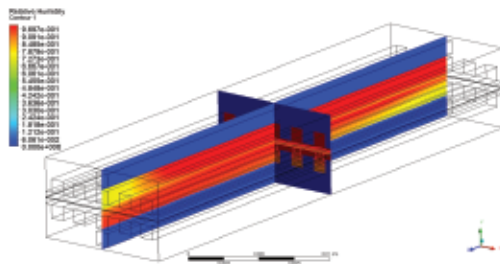
<http://pemfc.fesb.unist.hr>

Ultimate project objective:

develop a fuel cell which could be
operated without external
humidification of the reactant gases

Specific project objectives:

- ◆ Further investigation of the concept of spatially variable heat removal rate, which establishes a temperature profile along the cathode channel allowing the product water to humidify the air flowing through the cathode up to 100% relative humidity
- ◆ Study thermodynamics of water absorption and desorption and phase change at the polymer membrane surface
- ◆ Investigation of heat transfer process in catalyst layer nanostructures and established thermal conductivity
- ◆ Prove that the proposed concept would result in longer life than if the fuel cell is operated at uniform constant temperature
- ◆ Establish collaboration with other research groups in the EU

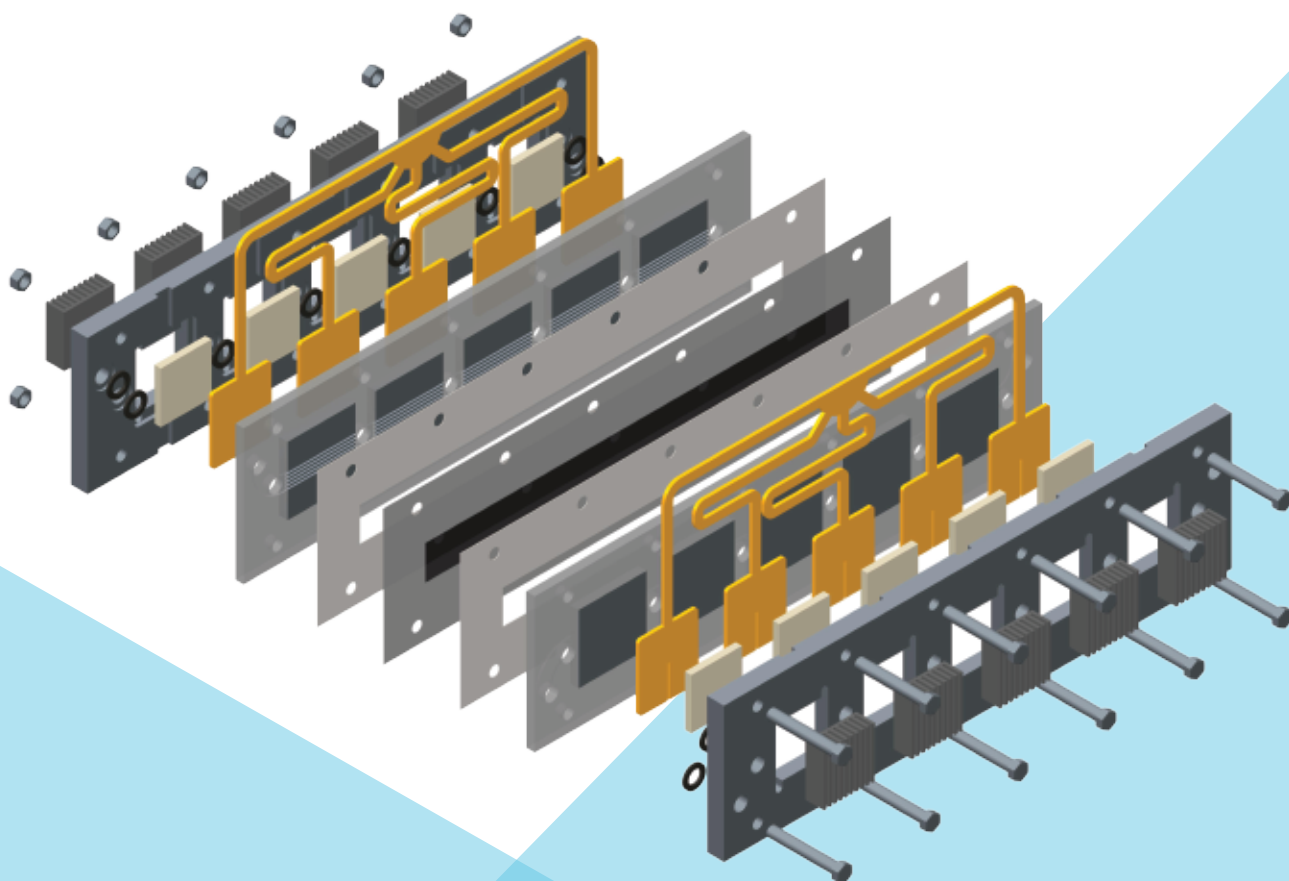


Project activities:

- ◆ Modeling of water transport through the membrane
- ◆ CFD modeling along the cathode channel
- ◆ Application of models to variable temperature concept
- ◆ Heat transfer in catalyst layer
- ◆ Experimental analysis of durability stressors and decay mechanisms
- ◆ Numerical methods for data analysis and diagnostics
- ◆ Design and install experimental set-up with verification of the modelling results at various current densities, variety of ambient conditions, different membrane thicknesses, and accelerated stress tests
- ◆ Better understanding of fuel cell behaviour during transient changes
- ◆ Develop strategy for fuel cell temperature control
- ◆ Design a fuel cell stack with incorporated variable temperature concept

Project team:

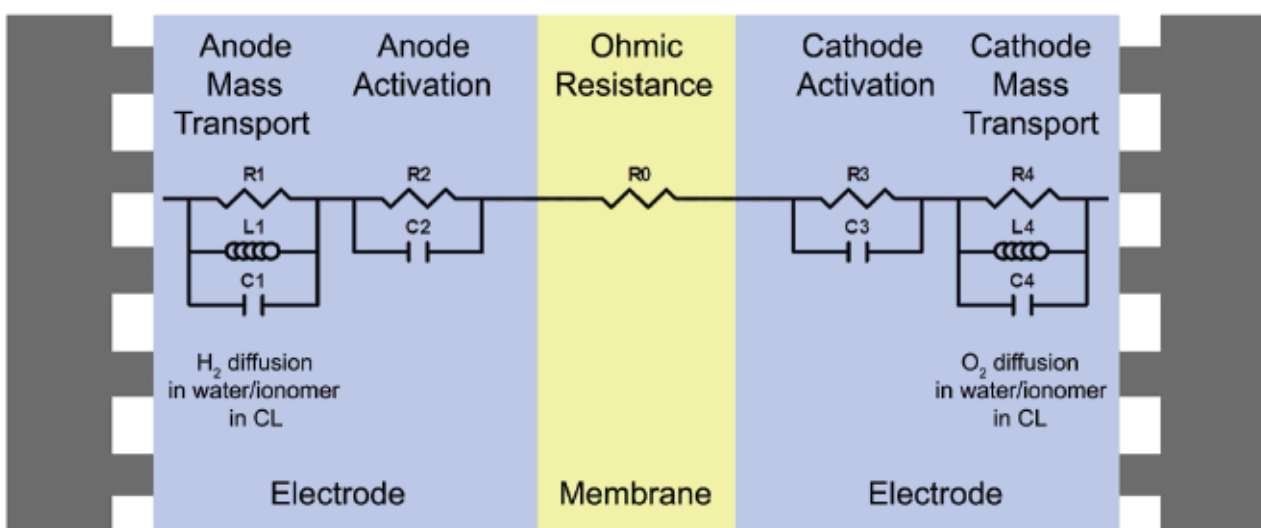
- prof. dr. sc. Frano Barbir – Project Leader
- dr. sc. Ivan Tolj – Post-doc
- dr. sc. Dario Bezmalinović – Post-doc (until September 30, 2017)
- dr. sc. Željko Penga – PhD student/ Post-doc (from July 21, 2017)
- prof. dr. sc. Gojmir Radica – Associate
- prof. dr. sc. Gojko Magazinović – Associate
- prof. emeritus dr. sc. Jagoda Radošević – Consultant
- prof. dr. sc. Paško Županović – Associate
- Ivan Pivac, mag. ing. mech. – PhD student
- Ivan Poljak, mag. phys. – PhD student
- Ivan Jurić, ing. el. – Laboratory Assistant (from May 1 to October 30, 2016)



PUBLICATIONS RESULTED FROM THE PROJECT ACTIVITIES:

Journal articles and review articles in CC journals:

1. I. Pivac, D. Bezmalinović, F. Barbir: *Catalyst degradation diagnostics of proton exchange membrane fuel cells using electrochemical impedance spectroscopy*, International Journal of Hydrogen Energy, In Press (2018)
2. I. Poljak, P. Županović, F. Barbir: *Measurement of Proton Concentration in PEM by Hall Effect*, Fuel Cells, In Press (2018)
3. Ž. Penga, I. Pivac, F. Barbir: *Experimental Validation of Variable Temperature Flow Field Concept for Proton Exchange Membrane Fuel Cells*, International Journal of Hydrogen Energy 42, 41 (2017) 26084-26093
4. I. Pivac, B. Šimić, F. Barbir: *Experimental diagnostics and modeling of inductive phenomena at low frequencies in impedance spectra of proton exchange membrane fuel cells*, Journal of Power Sources 365 (2017) 240-248
5. Ž. Penga, I. Tolj, F. Barbir: *Computational fluid dynamics study of PEM fuel cell performance for isothermal and non-uniform temperature boundary conditions*, International Journal of Hydrogen Energy 41 (2016), 39, 17585–17594
6. I. Pivac, F. Barbir: *Inductive phenomena at low frequencies in impedance spectra of proton exchange membrane fuel cells – A review*, Journal of Power Sources 326 (2016), 112-119

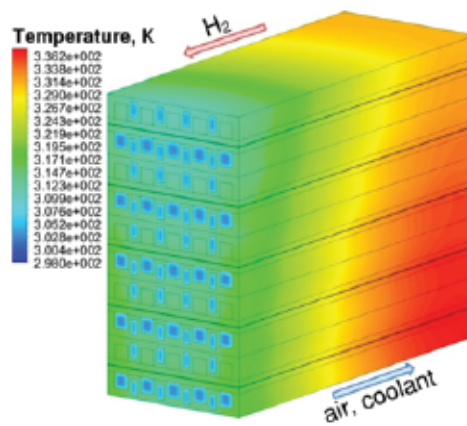
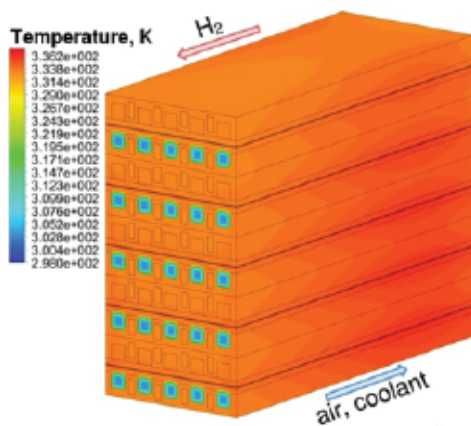
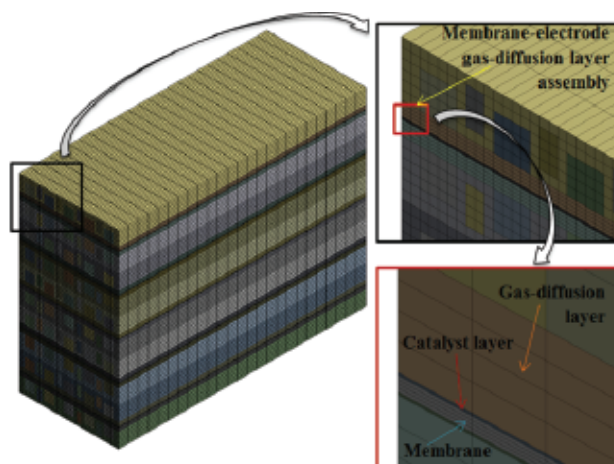
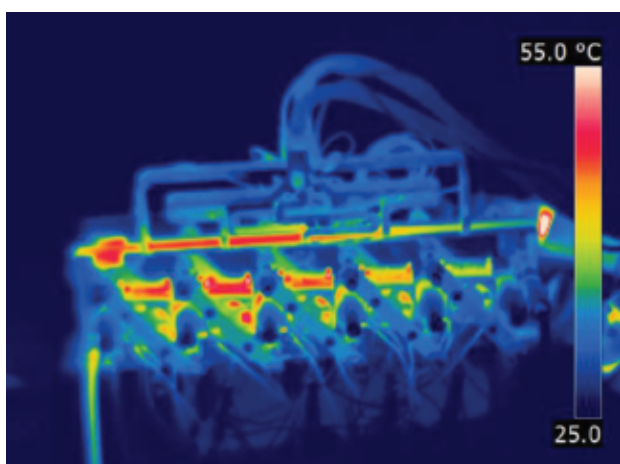
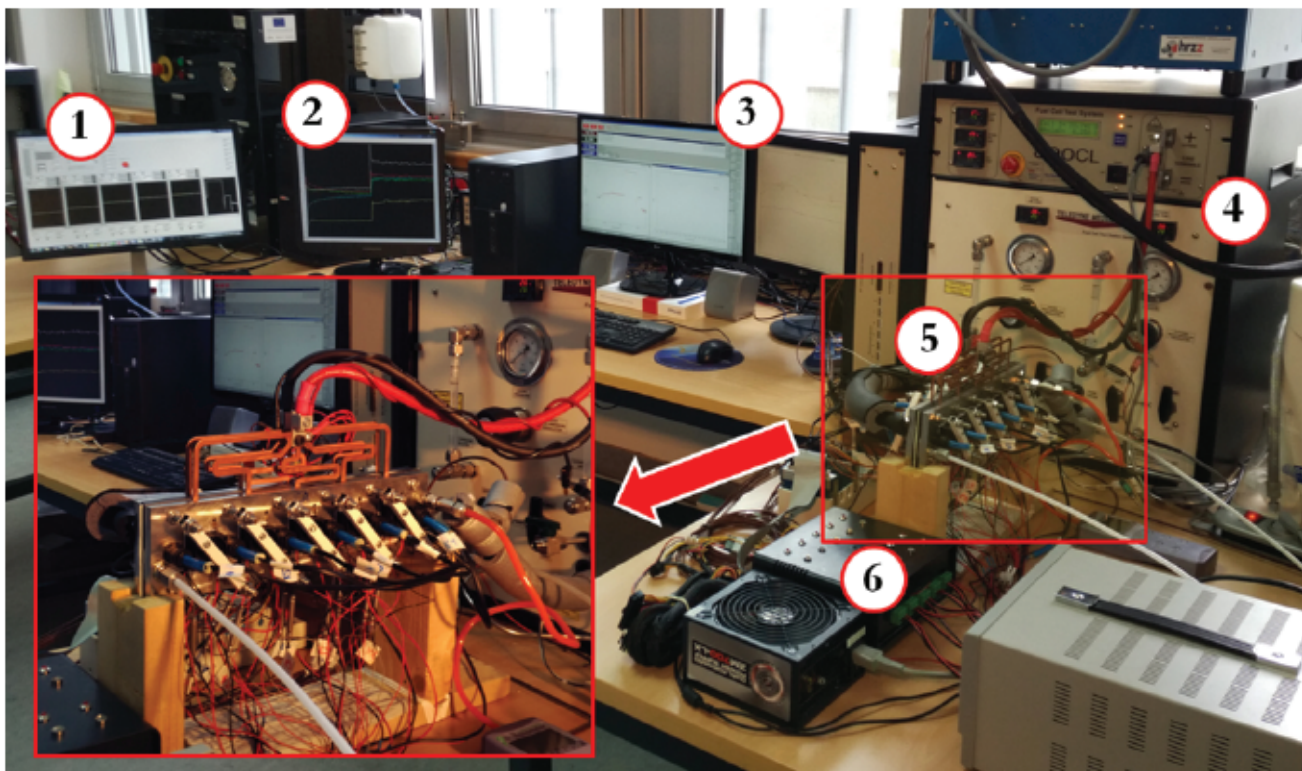


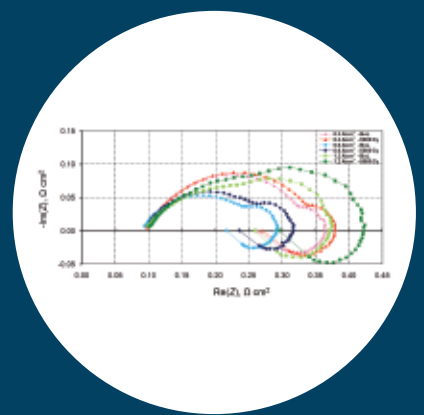
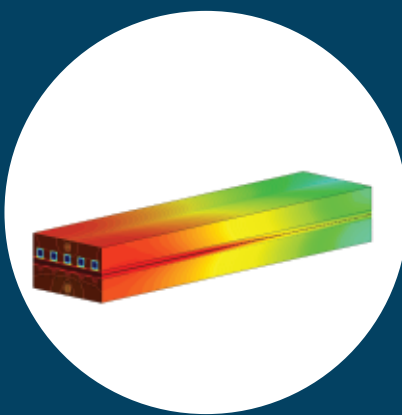
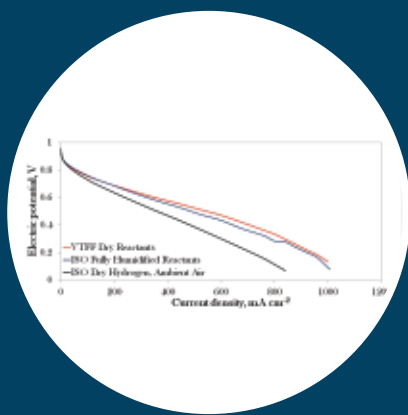
Scientific conference papers with international review:

1. I. Pivac, I. J. Halvorsen, D. Bezmalinović, F. Barbir, F. Zenith: *Low-frequency EIS intercept as a diagnostic tool for PEM fuel cells degradation*, European Fuel Cell Proceedings of the 7th European Fuel Cell Piero Lunghi Conference (EFC17, Naples) / Cigolotti, Viviana (ed.), ENEA, Rome, 2017. 231-232 (ISBN: 978-88-8286-356-2)
2. Ž. Penga, G. Radica, F. Barbir: *Computational Fluid Dynamics Analysis of Proton Exchange Membrane Fuel Cell Performance*, AVL International Simulation Conference 2017 (AVL ISC 2017, Graz), AVL, Graz, 2017. – CONFIDENTIAL
3. Ž. Penga, I. Pivac, I. Tolj, F. Barbir: *Tracking the process at PEM fuel cell cathode in h-x diagram*, Interklima 2017 24th International Symposium on Heating, Refrigerating and Air Conditioning (Interklima 2017, Zagreb) / Dović, Damir; Soldo, Vladimir; Mudrinić, Saša (ed), Sveučilište u Zagrebu, FSB, Zagreb, 2017. (ISSN 1848-0527)
4. Ž. Penga, F. Barbir: *Computational fluid dynamics model of high performance proton exchange membrane fuel cell without external humidification*, Energy and the Environment 2016, Opatija / B. Franković (ed.), Hrvatski savez za sunčevu energiju, Rijeka, 2016. 147-156 (ISBN: 978-953-6886-23-4)
5. I. Pivac, D. Bezmalinović, F. Barbir: *Electrochemical Impedance Spectroscopy for PEM Fuel Cell Degradation Diagnostics*, Proceedings of the 6th European Fuel Cell Piero Lunghi Conference (EFC15, Naples) / Cigolotti, Viviana (ed.), ENEA, Rome, 2015. 171-172 (ISBN: 978-88-8286-324-1)
6. I. Pivac, B. Šimić, D. Bezmalinović, F. Barbir: *Inductance at Low Frequencies in Electrochemical Impedance Spectroscopy of PEM Fuel Cells*, 5th European PEFC & H₂ Forum 2015 (EFCF 2015, Lucerne) / Barbir, Frano; Esposito, Angelo; Hissel, Daniel; Radica, Gojmir; Scholta, Joachim; Tolj, Ivan (ed.), European Fuel Cell Forum AG, Lucerne, 2015. Chapter 05 – 54-59 (ISBN: 978-3-905592-19-1)

Other scientific papers presented at international conferences:

1. F. Barbir, A. Alajbeg: *Efficiency analysis of the electrochemical hydrogen compressor*, 22nd World Hydrogen Energy Conference 2018 (WHEC 2018), Rio de Janeiro, 17-22 June, 2018
2. Ž. Penga, I. Pivac, F. Barbir: *Coolant Induced Variable Temperature Flow Field for PEM Fuel Cells: Experimental Validation of the Developed CFD Model*, 15th Symposium on Modeling and Experimental Validation of Electrochemical Energy Devices (ModVal 2018), Aarau, 12-13 April, 2018
3. F. Barbir, Ž. Penga, I. Pivac: *Segmented Fuel Cell for Verification of Variable Temperature Flow Field Concept*, 232nd ECS Meeting, National Harbor, USA, 1-5 October, 2017
4. Ž. Penga, I. Pivac, I. Tolj, F. Barbir: *Tracking the processes at PEM fuel cell anode and cathode in h-x diagram*, 9th International Exergy, Energy and Environment Symposium (IEEES-9), Split, 14-17 May, 2017
5. I. Pivac, F. Barbir: *Modeling of inductive phenomena at low frequencies in electrochemical impedance spectroscopy of PEM fuel cell*, 14th Symposium on Fuel Cell and Battery Modelling and Experimental Validation (ModVal 14), Karlsruhe, 2-3 March, 2017
6. Ž. Penga, I. Pivac, F. Barbir: *Segmented PEM fuel cell for verification of the variable temperature flow field concept*, 14th Symposium on Fuel Cell and Battery Modelling and Experimental Validation (ModVal 14), Karlsruhe, 2-3 March, 2017
7. I. Pivac, D. Bezmalinović, F. Barbir: *Istraživanje trajnosti membranskih gorivnih članaka*, 12. međunarodno znanstveno-stručno savjetovanje Energetska i procesna postrojenja (EIPP 2016), Rovinj, 16-18 November, 2016
8. I. Pivac, Z. Penga, F. Barbir: *Water Balance in Non-Humidified PEM Fuel Cell with Different Membrane Thicknesses*, PRiME 2016/230th ECS Meeting, Honolulu, 2-7 October, 2016
9. Ž. Penga, I. Pivac, I. Tolj, F. Barbir: *Variable temperature flow field for proton exchange membrane fuel cells*, 21st World Hydrogen Energy Conference 2016 (WHEC 2016), Zaragoza, 13-16 June, 2016





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