
Contents

| | |
|--|----|
| 1 Introduction | 1 |
| <i>E.I. Zoulias</i> | |
| 1.1 Background and Objectives | 1 |
| References..... | 3 |
| | |
| 2 Autonomous Fossil Fuel and Renewable Energy (RE)-based Power Systems | 5 |
| <i>A.S. Neris</i> | |
| 2.1 Introduction..... | 5 |
| 2.2 Generation Technologies in Autonomous Power Systems | 6 |
| 2.2.1 Renewable Generators | 6 |
| 2.2.2 Diesel Generators | 12 |
| 2.3 Technical Overview of Fossil-fuel and RE-based Autonomous Power Systems | 13 |
| 2.3.1 Autonomous Power System Configurations..... | 13 |
| 2.3.2 Stability Issues and Solutions | 14 |
| 2.3.3 Energy Management in Autonomous Power Systems..... | 16 |
| 2.4 Economic Evaluation..... | 18 |
| 2.4.1 Optimisation Problem Definition | 18 |
| 2.4.2 Simulation Methodology | 19 |
| References..... | 20 |
| | |
| 3 Integration of Hydrogen Energy Technologies in Autonomous Power Systems | 23 |
| <i>G.E. Marnellos, C. Athanasiou, S.S. Makridis and E.S. Kikkinides</i> | |
| 3.1 Introduction..... | 23 |
| 3.2 Hydrogen Production Technologies..... | 25 |
| 3.2.1 Introduction | 25 |
| 3.2.2 Hydrogen from Fossil Fuels | 28 |
| 3.2.3 Hydrogen from Splitting of Water..... | 33 |
| 3.2.4 Hydrogen from Biomass..... | 38 |

| | | |
|----------|--|------------|
| 3.2.5 | Current Technology, Prospects and Barriers on Hydrogen Production..... | 40 |
| 3.3 | Hydrogen Storage Technologies..... | 42 |
| 3.3.1 | Introduction..... | 42 |
| 3.3.2 | Basic Hydrogen Storage Technologies..... | 43 |
| 3.4 | Hydrogen Re-electrification Technologies..... | 52 |
| 3.4.1 | Introduction..... | 52 |
| 3.4.2 | Operation and Performance..... | 54 |
| 3.4.3 | Types of Fuel Cells – Technology Status..... | 58 |
| 3.4.4 | Fuel Cell Cost Considerations and Market Development..... | 64 |
| 3.5 | Conclusions..... | 72 |
| | References..... | 75 |
| 4 | Review of Existing Hydrogen-based Autonomous Power Systems – Current Situation..... | 83 |
| | <i>N. Lymberopoulos</i> | |
| 4.1 | Introduction..... | 83 |
| 4.2 | HYSOLAR Project..... | 83 |
| 4.3 | Solar-Wasserstoff-Bayern Project..... | 84 |
| 4.4 | Stralsund Project..... | 87 |
| 4.5 | FIRST Project..... | 88 |
| 4.6 | PHOEBUS Project..... | 89 |
| 4.7 | ENEA Wind-hydrogen Stand-alone System..... | 90 |
| 4.8 | PVFSYS System..... | 92 |
| 4.9 | UTSIRA Island Wind-hydrogen System..... | 93 |
| 4.10 | RES2H2 System..... | 95 |
| 4.11 | PURE System..... | 98 |
| 4.12 | HARI Project..... | 99 |
| | References..... | 100 |
| 5 | Techno-economic Analysis of Hydrogen Technologies Integration in Existing Conventional Autonomous Power Systems – Case Studies..... | 103 |
| | <i>E.I. Zoulias</i> | |
| 5.1 | Introduction..... | 103 |
| 5.2 | Methodology and Tools..... | 104 |
| 5.3 | Case Study 1: Gaidouromantra, Kythnos Island, Greece..... | 105 |
| 5.3.1 | System Description..... | 105 |
| 5.3.2 | Results and Discussion for the System of Kythnos..... | 106 |
| 5.4 | Case Study 2: Fair Isle, UK..... | 113 |
| 5.4.1 | System Description..... | 113 |
| 5.4.2 | Results and Discussion for the System of Fair Isle..... | 114 |
| 5.5 | Case Study 3: Rauhelleren, Norway..... | 120 |
| 5.5.1 | System Description..... | 120 |
| 5.5.2 | Results and Discussion for the System of Rauhelleren..... | 121 |
| 5.6 | Case Study 4: La Rambla del Agua, Spain..... | 126 |
| 5.6.1 | System Description..... | 126 |
| 5.6.2 | Results and Discussion for the System of Rambla del Agua..... | 127 |

| | | |
|----------|---|------------|
| 5.7 | Basic Principles for the Design and Optimization of Hydrogen-based Autonomous Power Systems | 132 |
| 5.7.1 | Methodology for the Design and Optimisation of Hydrogen-based Autonomous Power Systems | 132 |
| 5.7.2 | Conclusions from the Analysis of Case Studies | 134 |
| | References..... | 135 |
| 6 | Market Potential of Hydrogen-based Autonomous Power Systems..... | 137 |
| | <i>E.I. Zoulias</i> | |
| 6.1 | Introduction..... | 137 |
| 6.2 | Demand Side..... | 138 |
| 6.2.1 | Categorisation of the Demand Side | 139 |
| 6.2.2 | Market Segmentation..... | 145 |
| 6.3 | Supply Side..... | 147 |
| 6.3.1 | Operational Market Players | 147 |
| 6.3.2 | Market Drivers..... | 148 |
| 6.4 | Market Estimation..... | 149 |
| | References..... | 150 |
| 7 | Barriers and Benefits of Hydrogen-based Autonomous Power Systems . | 151 |
| | <i>T.D. Tsoutsos</i> | |
| 7.1 | Barriers for the Introduction of Hydrogen in Autonomous Power Systems | 151 |
| 7.1.1 | Introduction | 151 |
| 7.1.2 | The Results of H-SAPS Project..... | 152 |
| 7.2 | Hydrogen as a Measure to Increase RES Penetration in Isolated Power Systems | 153 |
| 7.2.1 | Introduction | 153 |
| 7.2.2 | Towards a 100% Autonomous Power Scheme..... | 154 |
| 7.2.3 | Conclusions – Economic Assessment | 154 |
| 7.3 | Environmental Benefits of Hydrogen-based Autonomous Power Systems | 155 |
| 7.3.1 | Estimates of Future Emissions | 155 |
| 7.3.2 | Environmental Impacts at a European Level..... | 156 |
| 7.3.3 | Potential Environmental Impacts..... | 157 |
| 7.3.4 | Methods of Estimation of the Environmental Impact of H-APS | 159 |
| | References..... | 161 |
| 8 | Roadmap to Commercialisation of Hydrogen-based Autonomous Power Systems..... | 163 |
| | <i>E.I. Zoulias</i> | |
| 8.1 | Introduction..... | 163 |
| 8.2 | Technology Roadmap for the Commercialisation of Hydrogen-based Autonomous Power Systems..... | 164 |
| 8.3 | Market Roadmap for the Commercialisation of Hydrogen-based Autonomous Power Systems..... | 167 |
| 8.4 | Energy Policy Roadmap for the Commercialisation | |

of Hydrogen-based Autonomous Power Systems 170

8.5 Recommendations for the Commercialisation
of Hydrogen-based Autonomous Power Systems 172

References..... 174

9 Conclusions..... 177

Index..... 181