Contents

FOREWORD .................................................. xiii
PREFACE .................................................. xvii
ACKNOWLEDGMENTS ....................................... xix
LIST OF FIGURES ......................................... xx
LIST OF ACRONYMS ....................................... xxv
WELCOME TO “ADVANCED SMART GRIDS” ............ xxxi

CHAPTER 1. DISTRIBUTION SYSTEM OPERATORS
IN A CHANGING ENVIRONMENT ............................ 1
   1.1. Energy policies promoting the energy transition ........................ 1
   1.2. A new era of technological revolution ............................ 9

CHAPTER 2. THE EXISTING DISTRIBUTION NETWORKS:
DESIGN AND OPERATION .................................. 13
   2.1. Above all, smart grids remain grids! .......................... 14
   2.2. The DSO, a player at the heart of the power system .............. 15
   2.3. A necessary mastery of technical and regulatory constraints ....... 18
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4. Generalities of network design</td>
<td>22</td>
</tr>
<tr>
<td>2.4.1. Energy transformers</td>
<td>24</td>
</tr>
<tr>
<td>2.4.2. Wiring and architectures</td>
<td>25</td>
</tr>
<tr>
<td>2.4.3. Safeguard devices</td>
<td>28</td>
</tr>
<tr>
<td>2.4.4. Sensors, digital equipment and software</td>
<td>29</td>
</tr>
<tr>
<td>2.4.5. The importance of telecommunication for operating the networks</td>
<td>31</td>
</tr>
<tr>
<td>2.5. The factors that differentiate network architecture</td>
<td>33</td>
</tr>
<tr>
<td>2.5.1. Voltage levels</td>
<td>34</td>
</tr>
<tr>
<td>2.5.2. The neutral point treatment in MV networks</td>
<td>36</td>
</tr>
<tr>
<td>2.5.3. The balance between automation, redundancy and reliability</td>
<td>39</td>
</tr>
<tr>
<td>2.5.4. The density and layout of the serviced area</td>
<td>40</td>
</tr>
<tr>
<td>2.5.5. The variation in building design</td>
<td>41</td>
</tr>
<tr>
<td>2.6. Network safety and planning</td>
<td>41</td>
</tr>
<tr>
<td>2.6.1. Development of distribution networks</td>
<td>43</td>
</tr>
<tr>
<td>2.6.2. Operating distribution networks</td>
<td>43</td>
</tr>
<tr>
<td>2.6.3. Studies in operational safety</td>
<td>44</td>
</tr>
<tr>
<td>2.6.4. Monte Carlo method</td>
<td>44</td>
</tr>
<tr>
<td>2.6.5. Some results from applying the Monte Carlo method</td>
<td>45</td>
</tr>
<tr>
<td>2.7. Progressive modernization of a distribution network – the French example.</td>
<td>46</td>
</tr>
<tr>
<td>2.7.1. Standardization (1950–1965) and expansion of the network (1965–1985)</td>
<td>47</td>
</tr>
<tr>
<td>2.7.2. Achieving a minimal quality level for every customer</td>
<td>48</td>
</tr>
<tr>
<td>2.7.3. Targeted improvement of quality according to needs</td>
<td>50</td>
</tr>
<tr>
<td>2.7.4. Progressive desensitization of networks toward climate hazards</td>
<td>51</td>
</tr>
</tbody>
</table>

CHAPTER 3. MAIN DRIVERS AND FUNCTIONS OF ADVANCED SMART GRIDS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1. Drivers of the evolution of distribution grids</td>
<td>53</td>
</tr>
</tbody>
</table>
3.1.1. Massive integration of renewable energy sources ........................................... 53
3.1.2. Contribution to the development of electric vehicle and the charging infrastructures ................................................................. 55
3.1.3. Implementation of new market mechanisms (peak shaving, capacity market, etc.) ................................................................. 57
3.1.4. Participation in the development of new uses contributing to energy efficiency .............................................................................. 60
3.1.5. Urban renewal and the rise of the smart city in favor of resource optimization .......................................................... 61
3.1.6. Integration of energy storage solutions ................................................................................................................................. 62
3.2. Main functions of the advanced smart grid ................................................................................................................................. 68
3.2.1. Toward dynamic network management by the distribution system operators .......................................................... 68
3.2.2. Structuring the target model based on key functions ................................................................................................................. 69
3.2.3. Enhancing efficiency in day-to-day grid operation ..................................................................................................................... 72
3.2.4. Ensuring network security, system control and quality of supply ......................................................................................... 75
3.2.5. Improving market functioning and customer service .............................................................................................................. 77
3.2.6. European network codes ......................................................................................................................................................... 79

CHAPTER 4. METERING: A CORE ACTIVITY OF THE DSOs ........................................... 81

4.1. Smart meters are key tools for the deployment of smart grids .................................................................................................. 81
4.2. A continuous improvement and innovation approach .................................................................................................................. 82
4.2.1. From manual to remote reading for mass market customers .................................................................................................. 82
4.2.2. 20 years of smart metering and remote reading for industrial clients .................................................................................. 83
4.3. AMI metering systems ................................................................................................................................................................. 84
4.4. Focus on Linky smart metering system .......... 90
4.4.1. Scope of the project .......................... 90
4.4.2. Architecture and technical choices .......... 92
4.4.3. A point on system operation .................. 94
4.4.4. Scalability and security of the Linky system ........................................ 99
4.4.5. Techno-economic analysis ..................... 100
4.5. Focus on G3-PLC technology ...................... 101
4.5.1. Communication principles of the power line carrier .......................................... 101
4.5.2. Different types of physical level PLC modulation technique .................................. 101
4.5.3. The characteristics of G3-PLC technology ...................................................... 105
4.5.4. G3-PLC is a mature standard .................. 109
4.6. The contribution of smart meters for the development of advanced smart grids .......... 111
4.6.1. France: Linky at the service of the distribution network .................................. 111

CHAPTER 5. FOCUS ON FLEXIBILITY OPTIONS .............. 119

5.1. Flexibility, a complementary tool for DSOs. ...................................................... 119
5.1.1. Introduction ..................................... 119
5.1.2. DSO needs in terms of flexibility ...................... 120
5.1.3. The value of flexibility .......................... 123
5.1.4. Alliander Smart Grids Cost Benefits Analysis (source: Alliander) ...................... 124
5.1.5. Two major categories of levers can be activated .............................................. 126
5.1.6. Analysis of the Merit Order ....................... 127
5.1.7. Information exchange mechanism between DSO and TSO ................................ 128
5.1.8. Lessons learned from several international business cases ............................ 128
5.2. Participation of end users to flexibility services. .............................................. 130
5.2.1. Introduction ..................................... 130
5.2.2. Focus on different tools and services downstream of the smart meter .............. 132
5.2.3. The necessary engagement of end-customers ........................................ 137
5.2.4. International benchmark and lessons learnt ........................................ 138
5.3. Data management as key success factor ................................................. 139
  5.3.1. DSOs have a long experience in data management .............................. 139
  5.3.2. DSO, the market facilitator ............................................................. 142

CHAPTER 6. PILOT PROJECTS AND USE CASES .......................................... 145
6.1. A global dynamic with regional specificities ......................................... 145
6.2. North America ....................................................................................... 147
  6.2.1. Drivers of smart grids development .................................................. 147
  6.2.2. Primary experimental approaches .................................................... 148
6.3. Asia ....................................................................................................... 150
  6.3.1. Drivers of smart grids development .................................................. 150
  6.3.2. A proactive experimental approach .................................................. 151
6.4. Europe .................................................................................................... 154
  6.4.1. Drivers of smart grids development .................................................. 154
  6.4.2. Primary experimental approaches .................................................... 157
6.5. The European project Grid4EU, fosters and accelerates experience sharing ................................................................. 158
  6.5.1. A large-scale demonstration project bringing together six European DSOs ................................................................. 158
  6.5.2. DEMO 1 (Germany – RWE) MV network operation automation and determining the ratio of decentralized intelligence in secondary substations ................................................................. 160
  6.5.3. DEMO 2 (Sweden – Vattenfal): a tool for LV operation and in particular identifying LV failures ................................................................. 161
  6.5.4. DEMO 3 (Spain – Iberdrola) MV and LV failure detection, reconfiguration of the MV network during an incident ................................................................. 162
  6.5.5. DEMO 4 (Italy – ENEL) economic model and technical operation of storage, MV voltage regulation, anti-islanding of decentralized generation ................................................................. 164
6.5.6. DEMO 5 (Czech Republic – CEZ) operating islanding with co-generation, MV and LV failure detection and reconfiguration of the MV network following an incident 165
6.5.7. DEMO6 (France – ERDF): project NiceGrid 167

6.6. An approach based on use cases 168
6.6.1. Definition 168
6.6.2. Advantages 169
6.6.3. The development of use cases 169

6.7. Focus on some advanced projects of the ISGAN case book about Demand Side Management 171
6.7.1. Denmark – EcoGrid EU 173
6.7.2. Japan – Kitakyushu Smart Community Creation Project 174
6.7.3. The Netherlands – PowerMatchingCity 175
6.7.4. Canada – a virtual power plant to balance wind energy 177

CHAPTER 7. SMART GRIDS ARE THE FUTURE FOR DSO 181

7.1. Advanced smart grids for DSOs worldwide 181
7.1.1. The evolution towards smart grids is ineluctable 181
7.1.2. The development of smart grids is a necessity for the DSOs 183
7.1.3. But also an opportunity 185

7.2. A necessary evolution of skills and jobs of the DSOs 186
7.2.1. Competences are necessary to conduct experimentations successfully and to get the most feedback from them 186
7.2.2. Once the experiments are finished, the resources and competences need to be reinforced in preparation for large-scale industrialization and deployment 187
7.3. The French electrical sector mobilizes: the “Smart Grids” plan ........................ 189

CHAPTER 8. KEY FINDINGS ............................. 193

8.1. Smart grids or the real network revolution .................................................. 193
   8.1.1. Smart grids .............................................. 194
8.2. More RES means more network ......................................................... 195
8.3. The DSO is a facilitator ................................................................. 196
8.4. Consumer or “consum’player”? ....................................................... 197
8.5. Smart meter at the service of smart grids ........................................... 199
8.6. A smart bubble? .............................................................................. 199
8.7. Invest to save? .................................................................................. 201
8.8. Smart grids: a genuine industrial opportunity ........................................ 201

BIBLIOGRAPHY .................................................. 203

INDEX .............................................................. 211