

# Contents

---

List of Authors .....	xxii
-----------------------	------

## I Construction, Operation, Measurement, Coordination

<b>1</b>	<b>Metamorphoses of an Offshore Wind Farm.....</b>	<b>3</b>
	<i>Björn Johnsen</i>	
1.1	In the Beginning Was the Sea.....	4
1.2	Prerequisites and Previous Experience .....	5
1.3	Foundation Concepts: Something New on the Sea Bed .....	5
1.4	Delayed Completion .....	6
1.5	Installation, Logistics and Cabling.....	7
1.6	Operation, Maintenance and Farm Control System .....	7
1.7	Money and Its Usages .....	8
1.8	Sources .....	9
<b>2</b>	<b>Who, What, When, Why and Above All – Where to?.....</b>	<b>11</b>
	<i>Björn Johnsen</i>	
2.1	Sources .....	13
<b>3</b>	<b>A Thousand Sensors, from the Blade Tip to the Bottom of the Sea.....</b>	<b>17</b>
	<i>Kai Herklotz, Thomas Neumann, Wilhelm Heckmann, Hans-Peter Link, Copy edited by Björn Johnson</i>	
3.1	Measurement Service: One for All .....	18
3.2	Coordination, Organisation, Exploitation.....	18
3.3	Tripod Is Also Hard to Access on Land .....	19
3.4	An Obstacle Course Before and out at Sea .....	20
3.5	The Tides and Maltreated Measuring Buoys .....	22
3.6	Only 30 % Accessible by Ship in Winter .....	23
3.7	Firmly Entrenched in the Ground, even with Scour Holes .....	24
3.8	Logistics: (No) Ship will Come .....	26
3.9	Just Keep on Going.....	27
3.10	Sources .....	27

## II Foundation and Support Structures

<b>4</b>	<b>A Firm Hold in Rough Seas.....</b>	<b>31</b>
	<i>Raimund Rolfes, Moritz Häckell, Tanja Griebmann, Text written by Björn Johnson</i>	
4.1	Introduction .....	32
4.2	The Tripod as Wave Breaker .....	32
4.3	Steel Structure with an Ideal Figure .....	33

4.4	Cavity and Grout .....	33
4.5	Rust on the Tube .....	34
4.6	Immersion Bath for the “Problem” Plates .....	35
4.7	Monitoring Is Everything .....	35
4.8	Scouring, the (Un)Known Entity .....	38
4.9	Scour Protection Using Concrete Chains .....	39
4.10	How Much Can a Pile Bear? .....	39
4.11	Close to Reality .....	40
4.12	A Software Puzzle Gets Put Together .....	41
4.13	Sources .....	43
<b>5</b>	<b>Life Goes on .....</b>	<b>45</b>
	<i>Raimund Rolfes, Tanja Griesmann, Text written by Björn Johnson</i>	
5.1	The Journey Is the Reward .....	46
5.2	Efficient Data Management .....	46
5.3	Research Put into Practice .....	47
5.4	Despite Rust and All that: Is There Anything After the End of Service Life? .....	47
5.5	Model Tests Are Good, but Are Calculation Models Better? .....	48
5.6	The Gordian Tube Knot .....	50
5.7	Where Will It All End – Automatic Service Life Calculation .....	51
5.8	Sources .....	51
<b>6</b>	<b>Please Avoid Tilting .....</b>	<b>53</b>
	<i>Werner Rücker, Pablo Cuéllar, Steven Georgi, Krassimire Karabeliov, Matthias Baeßler, Copy edited by Björn Johnsen</i>	
6.1	Everything Rests on the Pile .....	54
6.2	Pore Water Pressure: Even a Drop Weighs Heavy .....	54
6.3	Measuring and Expanding .....	55
6.4	Between Ground Subsidence and Pore Water Pressure .....	57
6.5	Extreme Storms Loosen Things up .....	57
6.6	The Burden with the Load Thereafter .....	58
6.7	Sources .....	58
<b>7</b>	<b>Uncharted Territory on the Seabed .....</b>	<b>61</b>
	<i>Matthias Baeßler, Pablo Cuéllar, Steven Georgi, Krassimire Karabeliov, Werner Rücker, Copy edited by Björn Johnsen</i>	
7.1	Getting the Balance Right .....	62
7.2	Observing and Monitoring .....	62
7.3	All Beginnings: The PC and a System Identification Procedure .....	63
7.4	Field Trials at the Bottom of the Berlin Glacial Valley .....	64
7.5	The Early Piles: Still Not Very Resilient .....	64
7.6	No Signal in Normal Operation .....	65
7.7	Testing out at Sea Still Not Completed .....	66
7.8	Outlook: Please Continue to Develop Countermeasures .....	67
7.9	Sources .....	67

### III Turbine Technology and Monitoring

<b>8</b>	<b>Long-Lived Despite Harsh Winds</b> .....	71
	<i>Jan Kruse, Copy edited by Björn Johnsen</i>	
8.1	<b>The Gearbox – Highly Stressed</b> .....	72
8.1.1	A Small Crane on Board Instead of a Big Jack-up Rig out at Sea .....	72
8.1.2	Sufficient Capacity for a Long Service Life .....	73
8.1.3	Online Oil Tests to Combat Salt in the Gears .....	74
8.2	<b>SCADA, Interfaces and the Like</b> .....	75
8.2.1	Standard Communication Interface .....	75
8.2.2	Closely Linked: Data Flow and Communication Technology .....	75
8.3	<b>Grid Integration of the 5M</b> .....	76
8.3.1	Power Plant Characteristics .....	76
8.3.2	System Services – the Wind Turbine on Grid .....	76
8.3.3	Successful Simulation: The Grid Simulator .....	76
8.4	<b>Intelligent Control</b> .....	77
8.4.1	Recently in the Tower: No Wobble .....	77
8.4.2	The End of “Manual Control” .....	78
8.5	<b>Sources</b> .....	78
<b>9</b>	<b>Wind in the Blades</b> .....	79
	<i>Jan Kruse, Copy edited by Björn Johnson</i>	
9.1	<b>What Is Required of Rotor Blades</b> .....	80
9.2	<b>The Work Packages for the New Blade</b> .....	80
9.2.1	In Abundance .....	80
9.2.2	Process Development and Mould-Making .....	81
9.2.3	Stackable Transport Racks and a Set of Prototype Blades .....	82
9.2.4	Blade Test and Measurement “in the Field” .....	82
9.3	<b>Advances Made by the Others</b> .....	83
9.4	<b>Outlook: What Have We Got from It, and What Can We Still Get from It?</b> .....	83
9.5	<b>Sources</b> .....	83
<b>10</b>	<b>The Wiser Blade Knows When to Yield</b> .....	85
	<i>Björn Johnsen</i>	
10.1	<b>Withstanding – and Exploiting – 100 Million Gusts of Wind</b> .....	86
10.2	<b>Turbulences from the Front</b> .....	86
10.3	<b>Act Early rather than too Late</b> .....	87
10.4	<b>Twisting Instead of Pitching?</b> .....	87
10.5	<b>By Bend or by Twist</b> .....	88
10.6	<b>The Bigger the Flap, the Easier the Influence</b> .....	88
10.7	<b>Don’t Just Work Backwards, Also Work Forwards for a Change</b> .....	90
10.8	<b>Sources</b> .....	90
<b>11</b>	<b>The “Exclusively Offshore” Wind Turbine</b> .....	91
	<i>Gerrit Haake, Annette Hofmann, Copy edited by Björn Johnsen</i>	
11.1	<b>Objectives</b> .....	92
11.2	<b>Forward Sweep Instead of Bending Moments</b> .....	92

11.3	Learning Objective: Ruggedness .....	93
11.4	Before We Take to the High Seas: Testing .....	95
11.5	Not Quite Like Your Living Room Yet: Climate Control in the Inner Tower .....	95
11.6	Maintaining Maintenance .....	97
11.7	Keeping in Touch .....	97
11.8	Keep Turning in High Wind ... ..	98
11.9	Helicopter Air-Drop Platform: Abseil! .....	98
11.10	Drivetrain in Long-Term Test .....	98
11.11	Sources .....	100
<b>12</b>	<b>Shooting into the Wind with Laser Beams .....</b>	<b>101</b>
	<i>Björn Johnsen</i>	
12.1	How It Works .....	102
12.2	Not Just Research for Research's Sake .....	102
12.3	Lidar Technology .....	103
12.3.1	Snowfall Test in Swabia .....	103
12.3.2	Scanner System and Specification Offshore .....	104
12.3.3	Wind Measurement Buoy on the Crest of a Wave? .....	104
12.4	The Burden of the Power Curve .....	105
12.4.1	From Wmo to Demo .....	105
12.4.2	Lidar on the Nacelle .....	106
12.5	Turbulent Wind Fields in Front and Behind .....	107
12.5.1	Inflow from the Front, Initial Investigations into System Control .....	107
12.5.2	Simulation Is Part of Testing .....	107
12.5.3	Like a Smoke Trail – the Wind Loads Behind the Turbine .....	108
12.6	Quo Vadis? New Offshore Measuring Method and FGW Guidelines .....	109
12.7	When the Nacelles Have Lidar .....	109
12.7.1	Modern Control Systems First React upon Wind Impact .....	109
12.7.2	Robust and Suitable for Industrial Use .....	110
12.7.3	Collective “Blade Feed Forward Control” Before the Wind Hits? .....	110
12.8	Sources .....	111
<b>13</b>	<b>“Get Out of My Wind” .....</b>	<b>113</b>
	<i>Björn Johnsen</i>	
13.1	Measure More with Multi-Lidar .....	114
13.2	A Deficit Is Obvious – Where the Wind Is Concerned .....	115
13.3	Satellites, Lidars and a Source Code .....	115
13.4	More Accuracy Without a Mainframe Computer .....	117
13.5	Sources .....	117
<b>14</b>	<b>The First Test for Offshore Turbines .....</b>	<b>119</b>
	<i>Björn Johnsen</i>	
14.1	Wish, Will and Achievement .....	120
14.2	Air and Power Curve: the Greatest Deviations by Stable Atmospheric Conditions .....	120
14.3	Measuring at Hub Height: The Standard Is Not Enough .....	120
14.4	What Is Really Going on Behind the Turbine? .....	121
14.5	Not Enough Chaos in the Simulation Model .....	123

14.6	When Super Computers Begin to Fume – Part I: In the Turbine and Around the Turbines.....	123
14.7	When Super Computers Begin to Fume – Part II: From Inflow to Distant Wake and to the Wake of the Whole Wind Farm .....	124
14.8	Verification of the Turbine Dynamics: First Steps .....	126
14.9	Integration and Identification .....	126
14.10	Despite All the Effort: Still Only Little “Strain Wear” .....	128
14.11	Load Monitoring from Only Standard Data? .....	129
14.12	Sources .....	130
<b>15</b>	<b>Load, Load Monitoring, and Load Reduction.....</b>	<b>131</b>
	<i>Björn Johnsen</i>	
15.1	Corrections Welcome.....	132
15.2	Interaction in a Different Way – the Tower Vibrates as well.....	133
15.3	Load-Reducing Regulation and Load Monitoring.....	134
15.4	Loads Along the Rotor Blades .....	134
15.5	Always Further, Always Higher? .....	134
15.6	Small Unmanned Aircraft: To New Heights Without Daedalus .....	134
15.7	... And with Ice on the Blade Tips.....	135
15.8	Did the Storm Contravene the Rule Book?.....	135
15.9	Sources .....	135
<b>16</b>	<b>Different than Previously Assumed .....</b>	<b>137</b>
	<i>Stefan Emeis, Copy edited by Björn Johnsen</i>	
16.1	Nobody Is Perfect – Not Even Fino.....	138
16.2	Not “Just Air”: Boundary Layers in the Atmosphere .....	138
16.3	Of Young and Old Waves .....	139
16.4	Describing the Sea Without Wave Data .....	141
16.5	Outlook .....	142
16.6	Sources .....	143
<b>17</b>	<b>Sometimes It Almost Bubbles Like a Witches’ Cauldron.....</b>	<b>145</b>
	<i>Stefan Emeis, Thomas Neumann, Richard Foreman, Beatriz Cañadillas, Copy edited by Björn Johnsen</i>	
17.1	Installation Takes Precedence over Studying .....	146
17.2	Over the Sea It’s Always on the Up and Up.....	147
17.3	Like in the Classroom: It Gets More Turbulent Behind the First Row.....	147
17.4	Outlook: Keep on Writing!.....	151
17.5	Sources .....	151
<b>18</b>	<b>Artificial Intelligence and Automatic Self-Organisation .....</b>	<b>153</b>
	<i>Stephan Oelker, Marco Lewandowski, Klaus-Dieter Thoben, Dirk Reinhold, Ingo Schlalos, Copy edited by Björn Johnsen</i>	
18.1	Wind Farms Inaccessible for Six Months? .....	154
18.2	Inspired by the Good Old Used Car .....	154
18.3	It Takes a Breakdown to Trigger the Maintenance Process .....	154
18.4	About the Peaceful Coexistence of Systems .....	155

18.5	Gathering Data: From Gear Oil to “Concert Pitch” of the Blade Rotation .....	155
18.6	The Process Machine Is Running .....	156
18.7	A Different Selection for Once: Please Present a Wide Range of Faults .....	157
18.8	When the Offshore Machines Negotiate About Maintenance with One Another .....	158
18.9	Sources .....	158
<b>19</b>	<b>Well, How are They Running?</b> .....	<b>159</b>
	<i>Berthold Hahn, Stefan Faulstich, Volker Berkhout, Copy edited by Björn Johnsen</i>	
19.1	Going from Land out to Sea .....	160
19.2	More Than Just Counting Kilowatt Hours .....	160
19.3	A Word in Your Ear: Confidentiality and Individual Evaluations .....	160
19.4	Involving the Actors: Persuasive Efforts .....	161
19.5	Events, Results – and a Library! .....	163
19.6	Zeus Makes It Possible .....	164
19.7	“IEA Wind Task” – More than Just a Talk Show .....	165
19.8	Over 200 Offshore Turbines Are Involved .....	165
19.9	Sources .....	167

## IV Grid Integration

<b>20</b>	<b>Wind, the Wild Boy in the Power Plant Family</b> .....	<b>171</b>
	<i>Arne Wessel, Sebastian Stock, Lüder von Bremen, Copy edited by Björn Johnsen</i>	
20.1	The Grid and Nothingness .....	172
20.2	Maintaining Voltage and Frequency .....	172
20.3	Together We Are Strong – Let’s “Cluster”! .....	173
20.4	The Main Thing Is What Comes out at the Other End .....	173
20.5	Most Frequently at Rated Output: Energy Yields and Power Fluctuation in Alpha Ventus .....	173
20.5.1	Fluctuations: The Wind Farm Compensates for Individual Turbines .....	175
20.5.2	It Gets Shady Starting with the Second Row .....	175
20.5.3	Never Quiet on the Western Front .....	175
20.5.4	Calm Is when It Still Blows: 16 Hours Bad, 20 Sad .....	177
20.6	Everything Flowing? From the Beginning of all Wind Power Forecasts to “Total Fluc” ..	178
20.6.1	More Accurate by the Dozen? A Weather Forecast Ensemble .....	180
20.6.2	Fluctuations Especially with North-Westerly Currents .....	181
20.7	From “Wild Bunch” to Power Plant Network .....	182
20.7.1	Trans Europe Express: What a Future Offshore Grid Might Look Like .....	182
20.7.2	Orderly Cluster Formation .....	183
20.7.3	Offshore Clustering Is Both Easier and More Difficult .....	184
20.7.4	Over 70 Grid Calculations for a Four-Hour Forecast .....	184
20.7.5	Operational Management Strategies .....	184
20.7.6	Not the End, but a New Beginning: The Wind Farm Simulator .....	185
20.8	Outlook: Control System and Last Instance .....	185
20.9	Sources .....	186

**V Environment and Ecology**

**21 The most Important Environmental Project in a German Offshore Wind Farm** ..... 189  
*Anika Beiersdorf, Maria Boethling, Axel Binder, Kristin Blasche, Nico Nolte, Christian Dahlke, Copy edited by Björn Johnsen*

21.1 **How It all Began** ..... 190

21.2 **The Go-Ahead for Knowledge** ... ..... 191

21.3 **If You Don't Know What to Do Next, Organise a Workshop** ..... 191

21.4 **The Results of the Environmental Research** ..... 192

21.4.1 **Impacts on Pelagic Fish** ..... 192

21.4.2 **Impacts on Demersal Fish and Crustaceans** ..... 192

21.4.3 **Result: Merged and Standardised Environmental Database** ..... 194

21.4.4 **The Claw, the Trawl Net and the Seabed** ..... 194

21.4.5 **Gannets and Friends: The Impacts on Sea and Migratory Birds** ..... 195

21.4.6 **Viewing and Evaluating Data on Seabirds** ..... 197

21.4.7 **Porpoise and Friends: Impacts on Marine Mammals** ..... 198

21.4.8 **Joint Evaluation of Data About Marine Mammals** ..... 199

21.4.9 **Marine Mammals and Ecological Habitat Modelling** ..... 199

21.4.10 **Piling and Operating Noise** ..... 199

21.4.11 **Underwater Noise: New Measuring Specifications** ..... 199

21.4.12 **International Publication** ..... 199

21.4.13 **Standard Investigation Concept: Where It Goes from Here** ..... 200

21.5 **The Most Relevant New Features in StUK** ..... 200

21.6 **Sources** ..... 201

**22 Much Hubble-Bubble About Nothing?** ..... 203  
*Raimund Rolfes, Jörg Rustemeier, Tanja Griefßmann, Text written by Björn Johnsen*

22.1 **Scaring off Porpoises and Soft Starts** ..... 204

22.2 **Small Bubbles, Big Impact** ..... 205

22.3 **Three Levels and One Curtain** ..... 206

22.4 **It's the Current that Does It** ..... 207

22.5 **There Is Need for Improvement** ..... 208

22.6 **Sources** ..... 210

**23 Like the Din in a University Canteen** ..... 211  
*Michael Benesch, Hermann van Radecke, Copy edited by Björn Johnsen*

23.1 **Measurements Virtually Only in the Baltic Sea to Date** ..... 212

23.2 **Divers at Work** ..... 212

23.3 **Wind and Waves Make It Possible: The Greater the Output, the Less the Noise** ..... 213

23.4 **Distant Shipping in the Background** ..... 214

23.5 **Offshore Piledriving Carries over here from 50 Kilometres** ..... 214

23.6 **Hearing Damage Improbable** ..... 215

23.7 **Sources** ..... 215

<b>24</b>	<b>Out of Sight, out of Mind?</b> .....	217
	<i>Gundula Hübner, Johannes Pohl, Copy edited by Björn Johnsen</i>	
24.1	Introduction .....	218
24.2	Intensive Surveys .....	218
24.3	2+2 Comparisons in the North and Baltic Seas.....	219
24.4	There Is Support, if ... ..	219
24.5	Safety of Shipping Desired .....	220
24.6	Problem Animals: Marine Mammals and Birds.....	220
24.7	Landscape, Sense of Home, Quality of Life.....	220
24.8	Reassuring Experiences After Start of Operation .....	222
24.9	Lack of Opportunities for Participation.....	223
24.10	World and Values After Fukushima ... ..	224
24.11	Conflict Avoidance and an Increase in Acceptance.....	224
24.12	Money Is Not Everything .....	225
24.13	What Do We Do During the Construction and Operational Phases? .....	225
24.14	Summary: Participation Processes in Large-Scale Infrastructure Projects .....	226
24.15	Sources .....	226

## VI Safety

<b>25</b>	<b>When the Nautilus Struggles During a Dive</b> .....	229
	<i>Raimund Rolfes, Moritz Fricke, Tanja Griefßmann, Text written by Björn Johnsen</i>	
25.1	Finding Solutions for Two Totally Contradictory Goals.....	230
25.2	A Transponder Rarely Comes Alone .....	230
25.3	Between Sea and PC: Sound Absorbers and Simulations.....	231
25.4	Good Weather Is Something Else – Measurements at Sea State 4 .....	232
25.5	The Fundamental Question on Alpha Ventus: What Do You Think About the Eco Assessment? .....	233
25.6	The “Seal Bell” Rings for Dinner at the Fishing Net .....	234
25.7	Short-Term Danger at the Foundation .....	234
25.8	Perfectly Normal Behaviour: Scarper, Stress, Avoid .....	234
25.9	Recommendations, for Others Also.....	234
25.10	Sources .....	235
<b>26</b>	<b>A Bit too Much Salt of the Earth</b> .....	237
	<i>Heiko Hinrichs, Thole Horstmann, Uta Kühne, Monika Mazur, Henry Seifert, Copy edited by Björn Johnsen</i>	
26.1	Look, Don’t Touch .....	238
26.2	Metal Plates Hung up Like Towels – to Rust .....	238
26.3	The Bremerhaven Salt Chamber .....	238
26.4	Swab Samples: Please Don’t Wipe the Microbes off .....	240
26.5	Temperature and Humidity in the Rotor Blade.....	241
26.6	Temperature and Humidity in the Nacelle .....	242
26.7	On the Trail of the Salt: The Detective that Never Slept .....	242
26.8	Automatic Measurement of Salt Deposits .....	243



26.9 Rearing Salt Crystals in the Lab ..... 244

26.10 Rendezvous at the Old Oil Pier ..... 244

26.11 Outlook ..... 245

26.12 Sources ..... 246

  

**27 SOS on Offshore Platform Seven ..... 247**

*Christine Carius, Christoph Jacob, Martin Schultz, Copy edited by Björn Johnsen*

27.1 What Has Happened up to Now ..... 248

27.2 In an Emergency: Nothing Works Without Communication ... ..... 248

27.3 ... And Nothing Works Without Wi-Fi! ..... 248

27.4 Audiovisual System: The Injured Person Feels Safer ..... 250

27.5 Prototype to Go: The TMBox ..... 250

27.6 In Future an App Instead of an Applicator? ..... 251

27.7 Sources ..... 252

Sea – Wind – Power

Research at the first German offshore wind farm Alpha  
Ventus

Durstewitz, M.; Lange, B. (Eds.)

2017, XXV, 252 p. 176 illus. in color., Hardcover

ISBN: 978-3-662-53178-5