

Contents

1	Introduction	1
1.1	Motivation and Goal	1
1.2	Approach	3
1.2.1	Qualitative Criteria	3
1.2.2	Quantitative Criteria	5
1.2.3	Structure	5
2	Background	7
2.1	Communication Alternatives for DERs	7
2.1.1	Control Stakeholders	7
2.1.2	IP-based Solutions	8
2.2	Substation Automation	9
2.2.1	Components and Functions	10
2.2.2	Communication Technology	12
2.3	IEC 61850	13
2.3.1	Standardization Bodies	13
2.3.2	Historical Development	14
2.3.3	Fundamental Concepts	15
2.3.4	Conformance Testing	20
3	Interoperability through Information Models	23
3.1	Introduction	23
3.2	Modeling Terminology	24
3.3	Modeling Rules	26
3.3.1	Server	27
3.3.2	Logical Device	27
3.3.3	Logical Node	28
3.3.4	Data Object	30
3.3.5	Array	31
3.3.6	Constructed Data Attribute	32
3.3.7	Basic Data Attribute	33
3.4	Profile Modeling Demonstration	33
3.4.1	Use Case	35

3.4.2	Micro-CHP Units	35
3.4.3	Control Hierarchy	36
3.4.4	Existing CHP Unit Models	37
3.4.5	Profile Design	38
3.5	The Model's Impact on Interoperability	43
3.5.1	Human Comprehensibility	43
3.5.2	Interchangeability and Plug and Play	45
3.6	Conclusion	46
4	Service Mapping Comparison	49
4.1	Existing Mappings	49
4.1.1	MMS	50
4.1.2	Web Services	51
4.1.3	XMPP	51
4.2	Comparison	53
4.2.1	Functionality	53
4.2.2	Security	53
4.2.3	Message Size	54
4.3	Conclusion	56
5	Implementation Design	61
5.1	OpenIEC61850	61
5.2	Representation of the Information Model	62
5.3	ACSI Services as Client API Functions	64
5.4	Mappings as Plug-Ins	67
5.5	Server API Design	68
5.6	Conclusion	70
6	Performance Analysis	73
6.1	Introduction	73
6.1.1	Performance Requirements	73
6.1.2	Related Work	74
6.1.3	Approach	75
6.1.4	ASN.1 and BER	75
6.2	MMS PDU Size	76
6.2.1	PER Instead of BER	76
6.2.2	Overhead Caused by the OSI Stack	77
6.3	Performance Profiling	79
6.3.1	Java Performance	81
6.3.2	Measurement Setup	82
6.3.3	Results	83
6.4	BER Coding Strategies	83
6.4.1	Coding Without the ASN.1 Definition	84

6.4.2	Coding Using the ASN.1 Definition	85
6.4.3	Tree Structure vs. Stream	86
6.4.4	Choosing a Strategy for IEC 61850 MMS	88
6.5	jASN1 - an Efficient BER Coder	90
6.5.1	Motivation	90
6.5.2	Compiler	91
6.5.3	Performance Optimization	91
6.5.4	Performance Comparison	92
6.6	Stack Performance	94
6.7	Conclusion	97
7	Comparison with Metering Protocols	99
7.1	Introduction	99
7.1.1	IEC 61850 for Metering	100
7.1.2	DLMS/COSEM	100
7.1.3	SML	100
7.2	Comparison	101
7.2.1	Functionality	101
7.2.2	Interoperability Through Information Models	103
7.2.3	Message Size	105
7.3	Conclusion	108
8	Comparison with OPC UA	111
8.1	OPC UA	111
8.2	Comparison	113
8.2.1	Functionality	113
8.2.2	Interoperability Through Information Models	116
8.2.3	Security	119
8.2.4	Message Size	122
8.2.5	Processing Performance	125
8.3	Conclusion	128
9	Conclusion	131
A	List of Abbreviations	135
B	Protocol Messages	139
C	ASN.1 Example	143
D	OPC UA Message Structures as ASN.1	145
E	Acknowledgements	149

F Scientific Activity	151
F.1 Publications	151
F.2 Supervision of Student Theses	152
Bibliography	153