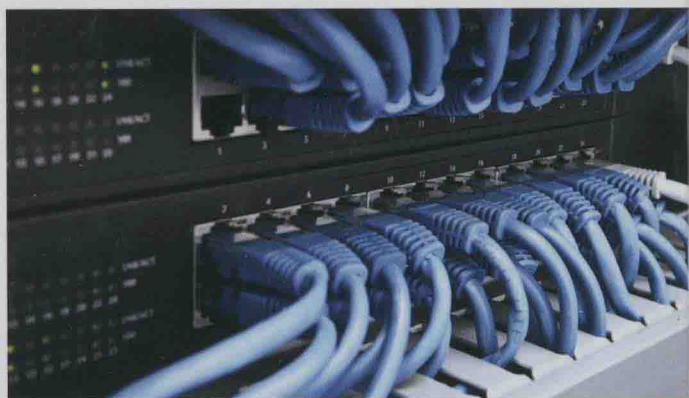


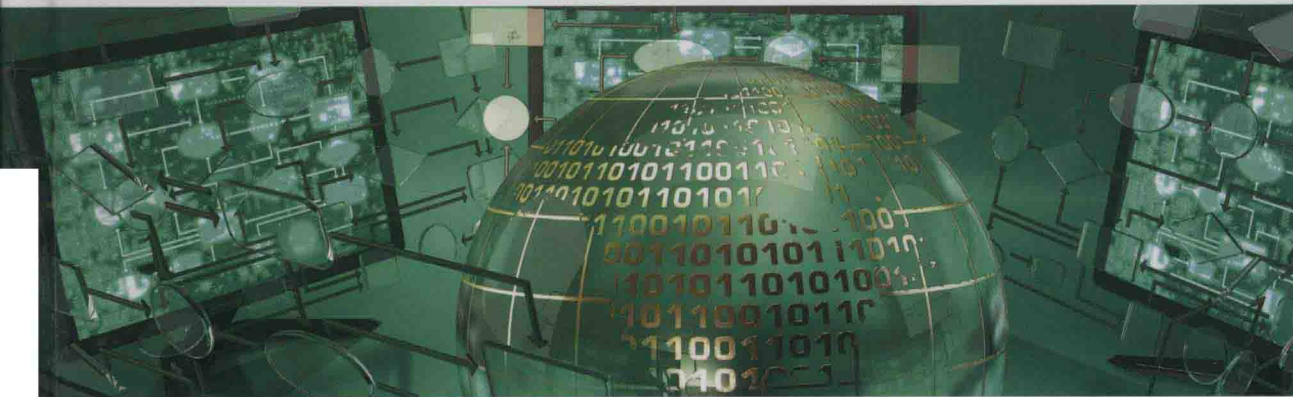


Substation Automation Systems

Design and Implementation



Evelio Padilla



WILEY

SUBSTATION AUTOMATION SYSTEMS DESIGN AND IMPLEMENTATION

Evelio Padilla

Eleunion C.A., Caracas, Venezuela

WILEY

This edition first published 2016
© 2016 John Wiley & Sons, Ltd.

Registered Office

John Wiley & Sons, Ltd., The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

The advice and strategies contained herein may not be suitable for every situation. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of experimental reagents, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each chemical, piece of equipment, reagent, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

Library of Congress Cataloging-in-Publication Data

Padilla, Evelio.

Substation automation systems : design and implementation / Evelio Padilla, Eleunion, Venezuela.

pages cm

Includes bibliographical references and index.

ISBN 978-1-118-98720-9 (cloth)

1. Electric substations--Automatic control. I. Title.

TK1751.P33 2016

621.31'26--dc23

2015021965

A catalogue record for this book is available from the British Library.

Set in 10/12pt Times by SPi Global, Pondicherry, India

Printed and bound in Singapore by Markono Print Media Pte Ltd

SUBSTATION AUTOMATION SYSTEMS

Preface

A number of technological changes have occurred in the substation environment over the last 30 years. Surge arresters built with metal oxide discs, circuit breakers isolated with SF₆ gas, numerical protective relays and other novel products that appeared early in the 1980s, were quickly adopted without significant impact on substation design. A few years after, however, the incursion of digital technology caused a “jerk” in the field of substation secondary systems. While young system engineers with a limited knowledge in substation-related concepts have become engaged in development of the engineering process Substation Automation Systems (SASs) from the side of device manufacturers, experienced utilities personnel had to (and in some cases still need to) face up to many disconcerting and complex scenarios characterized by an unusual lexicon and a lot of abstract resources that are now being applied to define and implement control and monitoring functionalities in their substations.

This book intends to help both professional groups accomplish their responsibilities by giving them guidelines with respect to the scope and functions of SASs based on current technology, including requirements from Standard IEC 61850, as well useful details for dealing with various stages needed for SAS project development.

The material is organized into 19 chapters; Chapter 1 providing a brief review on how SAS has recently evolved, Chapter 2 outlines the purpose of the SAS as an essential part of the substation, in Chapter 3 the effects of Standard IEC 61850 on different stages of SAS projects are presented, Chapter 4 illustrates constructive and functional features of equipment that make up the primary power circuit, Chapter 5 introduces the characteristics of Intelligent Electronic Devices (IEDs) used for control and monitoring and describe briefly certain phenomenon able to affect in detrimental way the physical/functional integrity of such devices, Chapter 6 provides an overview of how the features and functions of devices installed into the main control house are used for controlling and monitoring the substation as a whole, Chapter 7 contains different SAS functionalities including switching commands and constraints like interlocking and blocking conditions, Chapter 8 shows the set of signals coming from different substation components that need to be managed by the SAS, Chapter 9 suggests how the SAS ought to be engineered, Chapter 10 covers the theory and practical principles that support a typical

implementation needed for the substation control and monitoring from a remote master station, Chapter 11 describes a lot of items that may characterize the SAS structure including options for the network topology further to quality requirements and cyber-security considerations, Chapter 12 contains recommendations regarding the tests to carry out on SAS components, Chapter 13 may serve as a baseline for programming and checking results of Factory Acceptance Tests (FATs) performed on representative SAS segments, Chapter 14 covers site testing scope and strategies, Chapter 15 proposes scope and sequence of training programs addressed to utilities personnel, Chapter 16 outlines how to deal with SAS projects, Chapter 17 offers a number of tips useful to help in getting timely acceptable SAS components and functionalities, Chapter 18 summarizes resources to be used and methodology to be followed for the engineering process according to Standard IEC 61850, and finally, Chapter 19 forecasts where control and monitoring technologies may go in the future.

In summary, the book intends to serve the practical needs of different participants in SAS projects with respect to technical matter and also from the management perspective.

Evelio Padilla

Acknowledgments

I would like to gratefully acknowledge several people for their valuable help on this book.

Firstly to all Wiley staff including Laura Bell, Assistant Editor, who was my initial contact with the company (and subtly followed with the publishing idea); Peter Mitchell, Publisher, Electrical Engineering, who achieved the tremendous goal of getting approval for the book project; Ella Mitchell, Associate Commissioning Editor, ever enthusiast in charge of extensive previous details and formal arrangements for the book project; Richard Davis, initial Project Editor, who gave me the guidelines related to the process for writing the book; Prachi Sinha Sahay, temporary Project Editor, who with patience and wisdom dealt with the completed manuscript, and Liz Wingett, the Project Editor who masterly cooperated in the process of adding value to the entire manuscript.

Thanks to Professors Nelson Bacalao and Greg Woodworth of Siemens Energy, who, as reviewers of the book project, found it to be feasible and contributinal to the power industry.

My daughter, Jessenia, and her husband, Vinicio, provided me with precious and constant support and encouragement during the preparation of the manuscript.

My partner, Maria, was generous in her understanding and patience during the writing process.

I am also grateful for the training and support received from my employer EDELCA (currently CORPOELEC), as well as Carabobo University for my higher degree education.

CORPOELEC kindly gave their permission to include all the photos that appear in the book.

Yunio Leal, Julio Aponte and Zurima Alfonzo were outstanding collaborators during my working stay in EDELCA.

My appreciation is also expressed to my parents, Juanpa and Clara Rosa, who supported my early education; to my brother, Elias, and my sister, Argelia, for always identifying with my professional career; my sons, Armando and Alejandro, permanent inspiration sources, and mathematician, Professor Daniel Labarca, who inspired me to become an engineering professional.

Finally, the biggest thanks to God; because without His guidance, nothing is possible.

Evelio Padilla

List of Abbreviations

| | |
|-------|--|
| AC | Alternating voltage system |
| A/D | Analog/digital |
| APT | Auxiliary power transformer |
| AV | Analog value |
| BB | Busbar |
| BC | Bay controller |
| BC-AS | Bay controller for auxiliary system |
| BF | Breaker failure |
| BI | Binary input |
| BIL | Basic impulse level |
| BO | Binary output |
| BPD | Bushing potential device |
| CB | Circuit breaker |
| CIGRE | International Council on Large Electric Systems (Conseil International des Grands Réseaux Électriques) |
| CPU | Central processing unit |
| CT | Current transformer |
| DB | Database |
| DC | Direct voltage system |
| DG | Diesel generator |
| DI | Disconnecter |
| DR | Disturbance recorder |
| DNP | Distributed network protocol |
| EMC | Electromagnetic compatibility |
| EMI | Electromagnetic interference |
| ES | Earthing switch |
| GOOSE | Generic object oriented substation event |
| GPS | Global positioning system |
| HMI | Human machine interface |

| | |
|-----------------|---|
| HV | High voltage |
| HW | Hardware |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| IED | Intelligent electronic device |
| IT | Information technology |
| I/O | Input/output |
| LAN | Local area network |
| LCD | Local control display |
| LV | Low voltage |
| MCB | Mini circuit breaker |
| MMS | Manufacturing message specification |
| MTTF | Mean time to failure |
| MU | Merging unit |
| MV | Medium voltage |
| MVA | Mega-volt ampere |
| NCC | Network control center |
| OLTC | On-load tap changer |
| OPGW | Optical grounding wire |
| PB | Process bus |
| PC | Personal computer |
| PCG | Protocol converter gateway |
| PR | Protective relay |
| PT | Power transformer |
| RTU | Remote terminal unit |
| SAS | Substation automation system |
| SB | Station bus |
| SC | Station controller |
| SCL | Substation configuration description language |
| SF ₆ | Sulfur hexafluoride |
| SLD | Single line diagram |
| SOE | Sequence of events |
| SV | Sampled values |
| SVC | Static var compensator |
| VT | Voltage transformer |

Contents

| | |
|---|-------------|
| Preface | xv |
| Acknowledgments | xvii |
| List of Abbreviations | xix |
| | |
| 1 Historical Evolution of Substation Automation Systems (SASs) | 1 |
| 1.1 Emerging Communication Technologies | 4 |
| 1.1.1 Serial Communication | 4 |
| 1.1.2 Local Area Network | 4 |
| 1.2 Intelligent Electronic Devices (IEDs) | 5 |
| 1.2.1 Functional Relays | 5 |
| 1.2.2 Integrated Digital Units | 5 |
| 1.3 Networking Media | 5 |
| 1.3.1 Fiber-Optic Cables | 5 |
| 1.3.2 Network Switches | 5 |
| 1.4 Communication Standards | 6 |
| 1.4.1 IEC Standard 61850 (<i>Communication Networks and Systems for Power Utility Automation</i>) | 6 |
| 1.4.2 IEEE Standard 802.3 (<i>Ethernet</i>) | 6 |
| Further Reading | 8 |
| | |
| 2 Main Functions of Substation Automation Systems | 9 |
| 2.1 Control Function | 14 |
| 2.2 Monitoring Function | 15 |
| 2.3 Alarming Function | 16 |
| 2.4 Measurement Function | 17 |
| 2.5 Setting and Monitoring of Protective Relays | 17 |
| 2.6 Control and Monitoring of the Auxiliary Power System | 17 |
| 2.7 Voltage Regulation | 18 |
| Further Reading | 18 |

| | | |
|----------|---|-----------|
| 3 | Impact of the IEC 61850 Standard on SAS Projects | 19 |
| 3.1 | Impact on System Implementation Philosophy | 21 |
| 3.2 | Impact on User Specification | 21 |
| 3.3 | Impact on the Overall Procurement Process | 23 |
| 3.4 | Impact on the Engineering Process | 23 |
| 3.5 | Impact on Project Execution | 23 |
| 3.6 | Impact on Utility Global Strategies | 24 |
| 3.7 | The Contents of the Standard | 24 |
| 3.8 | Dealing with the Standard | 24 |
| | Further Reading | 27 |
| 4 | Switchyard Level, Equipment and Interfaces | 29 |
| 4.1 | Primary Equipment | 29 |
| 4.1.1 | <i>Switchgear</i> | 31 |
| 4.1.1.1 | <i>Circuit Breaker</i> | 31 |
| 4.1.1.2 | <i>Disconnecter</i> | 32 |
| 4.1.1.3 | <i>Earthing Switch</i> | 33 |
| 4.1.2 | <i>Instrument Transformers</i> | 34 |
| 4.1.2.1 | <i>Voltage Transformer</i> | 34 |
| 4.1.2.2 | <i>Current Transformer</i> | 34 |
| 4.1.3 | <i>Power Transformers</i> | 35 |
| 4.1.4 | <i>Other Primary Equipment</i> | 38 |
| 4.2 | Medium and Low Voltage Components | 39 |
| 4.3 | Electrical Connections between Primary Equipment | 40 |
| 4.3.1 | <i>Incoming Circuits</i> | 42 |
| 4.3.2 | <i>Outgoing Circuits</i> | 42 |
| 4.3.3 | <i>The “Bay” Concept</i> | 43 |
| 4.4 | Substation Physical Layout | 43 |
| 4.5 | Control Requirements at Switchyard Level | 44 |
| | Further Reading | 46 |
| 5 | Bay Level: Components and Incident Factors | 49 |
| 5.1 | Environmental and Operational Factors | 49 |
| 5.1.1 | <i>Lightning Strike</i> | 49 |
| 5.1.2 | <i>Switching Transients</i> | 50 |
| 5.1.2.1 | <i>Disconnecter Operation</i> | 50 |
| 5.1.2.2 | <i>Circuit Breaker Operation</i> | 51 |
| 5.1.3 | <i>Electromagnetic Disturbance Phenomenon</i> | 51 |
| 5.1.4 | <i>Lightning Protection Practices</i> | 52 |
| 5.1.5 | <i>Typical Earthing Systems</i> | 54 |
| 5.1.6 | <i>Measures to Minimize Electromagnetic Effects</i> | 56 |
| 5.2 | Insulation Considerations in the Secondary System | 57 |
| 5.3 | Switchyard Control Rooms | 57 |
| 5.4 | Attributes of Control Cubicles | 59 |
| 5.4.1 | <i>Constructive Features</i> | 59 |
| 5.4.2 | <i>Earthquake Withstand Capability</i> | 59 |
| 5.4.3 | <i>Electromagnetic Compatibility</i> | 60 |

| | | |
|----------|---|-----------|
| 5.5 | The Bay Controller (BC) | 60 |
| 5.6 | Other Bay Level Components | 61 |
| 5.7 | Process Bus | 62 |
| | Further Reading | 63 |
| 6 | Station Level: Facilities and Functions | 65 |
| 6.1 | Main Control House | 65 |
| 6.2 | Station Controller | 67 |
| 6.3 | Human Machine Interface HMI | 68 |
| 6.3.1 | <i>Start-Up Screen</i> | 69 |
| 6.3.2 | <i>Main Box Screen</i> | 69 |
| 6.3.3 | <i>Users Administrator Screen</i> | 69 |
| 6.3.4 | <i>Primary Circuit Screen (Process Screen)</i> | 71 |
| 6.3.5 | <i>SAS Scheme Screen</i> | 71 |
| 6.3.6 | <i>Event List Screen</i> | 71 |
| 6.3.7 | <i>Alarm List Screen</i> | 72 |
| 6.4 | External Alarming | 73 |
| 6.5 | Time Synchronization Facility | 74 |
| 6.6 | Protocol Conversion Task | 74 |
| 6.6.1 | <i>Briefing on Digital Communication Protocols</i> | 75 |
| 6.6.2 | <i>Premises for Developing Protocol Conversion</i> | 76 |
| 6.7 | Station Bus | 77 |
| 6.8 | Station LAN | 77 |
| | Further Reading | 77 |
| 7 | System Functionalities | 79 |
| 7.1 | Control Function | 79 |
| 7.1.1 | <i>Control of Primary Switchgear</i> | 81 |
| 7.1.1.1 | <i>Symbols, Colors and Appearance Representing Primary Switchgear</i> | 81 |
| 7.1.1.2 | <i>Switching Command Implementation</i> | 81 |
| 7.1.1.3 | <i>Supervision of Circuit Breaker Trip Circuit</i> | 82 |
| 7.1.2 | <i>Check of Voltage Synchronization (Synchrocheck)</i> | 82 |
| 7.1.3 | <i>Checking Operative Constraint</i> | 83 |
| 7.1.3.1 | <i>Checking of Interlocking Conditions</i> | 83 |
| 7.1.3.2 | <i>Checking of Blocking Conditions</i> | 84 |
| 7.1.4 | <i>Voltage Regulation Task</i> | 84 |
| 7.1.5 | <i>Parallel Working of Power Transformers</i> | 85 |
| 7.1.6 | <i>Operation of Secondary Components</i> | 85 |
| 7.1.7 | <i>Facilities for Operation under Emergency Conditions</i> | 86 |
| 7.2 | Monitoring Function | 86 |
| 7.2.1 | <i>Event Handling</i> | 86 |
| 7.2.2 | <i>External Disturbance Recording</i> | 87 |
| 7.2.3 | <i>Alarming Management</i> | 87 |
| 7.3 | Protection Function | 88 |
| 7.4 | Measuring Function | 89 |

| | | |
|----------|--|------------|
| 7.5 | Metering Function | 89 |
| 7.6 | Report Generation Function | 89 |
| 7.7 | Device Parameterization Function | 90 |
| | Further Reading | 90 |
| 8 | System Inputs and Outputs | 91 |
| 8.1 | Signals Associated with Primary Equipment | 91 |
| 8.1.1 | Switchgear | 91 |
| 8.1.1.1 | Signals Associated with Circuit Breakers | 91 |
| 8.1.1.2 | Signals Associated with Disconnectors | 92 |
| 8.1.1.3 | Signals Associated with Earthing Switches | 92 |
| 8.1.2 | Instrument Transformers | 92 |
| 8.1.2.1 | Signals Associated with Voltage Transformers | 92 |
| 8.1.2.2 | Signals Associated with Current Transformers | 95 |
| 8.1.3 | Power Transformers | 95 |
| 8.2 | Signals Associated with the Auxiliary Power System | 95 |
| 8.2.1 | Signals Associated with MV Circuit Breakers | 95 |
| 8.2.2 | Signals Associated with MV Distribution Transformers | 97 |
| 8.2.3 | Signals Associated with LV Circuit Breakers | 97 |
| 8.2.4 | Signals Associated with Distribution Center "A" | 98 |
| 8.2.5 | Signals Associated with Distribution Center "B" | 98 |
| 8.2.6 | Signals Associated with AC Distribution Cubicles for Essential Loads | 98 |
| 8.2.7 | Signals Associated with Diesel Generators | 100 |
| 8.2.8 | Signals Associated with AC Distribution Cubicles for Nonessential Loads | 100 |
| 8.2.9 | Signals Associated with DC Transfer Switches | 101 |
| 8.2.10 | Signals Associated with DC Distribution Cubicles | 101 |
| 8.2.11 | Signals Associated with Each Voltage Level of Batteries and Chargers | 101 |
| 8.3 | Signals Associated with Collateral Systems | 102 |
| 9 | System Engineering | 103 |
| 9.1 | Overall System Engineering | 103 |
| 9.1.1 | System General Concept | 104 |
| 9.1.2 | System Topology | 104 |
| 9.1.3 | Opportune Clarifications | 105 |
| 9.1.4 | Premises for Engineering Work | 107 |
| 9.1.5 | Signals Lists | 109 |
| 9.1.5.1 | Signals List Related to the Bay Controller | 110 |
| 9.1.5.2 | Signals List Related to Bay Controller of the Auxiliary Power System | 110 |
| 9.1.5.3 | Signals List Related to the Station Controller | 110 |
| 9.1.5.4 | Signals List for Communication with the NCC | 110 |
| 9.1.5.5 | Point to Point Signals List (For Each Bay) | 110 |
| 9.1.5.6 | Signals Lists Related to Equipment and Systems | 111 |
| 9.2 | Bay Level Engineering | 111 |

| | | |
|-----------|--|------------|
| 9.3 | Station Level Engineering | 112 |
| 9.3.1 | Engineering Related to the Station Controller | 113 |
| 9.3.1.1 | Definition and Implementation of the Station Level Database (Process Database) | 113 |
| 9.3.1.2 | Implementation of Redundant Solutions | 114 |
| 9.3.2 | Engineering Related to the Human Machine Interface | 114 |
| 9.3.2.1 | General Design Principles | 115 |
| 9.3.2.2 | Typical Screens | 115 |
| 9.3.2.3 | Operative Features | 116 |
| 9.4 | Functionalities Engineering | 116 |
| 9.4.1 | Interlocking Engineering | 116 |
| 9.4.2 | Voltage Regulation Engineering | 117 |
| 9.4.3 | Protection Engineering | 117 |
| 9.4.4 | Metering Engineering | 117 |
| 9.4.5 | Disturbance Recording Engineering | 117 |
| 9.4.6 | System Self-Monitoring Engineering | 118 |
| 9.5 | Auxiliary Power System Engineering | 118 |
| 9.5.1 | Design Concept | 118 |
| 9.5.2 | AC Voltage Distribution | 118 |
| 9.5.3 | DC Voltage Distribution | 119 |
| 9.5.4 | Batteries and Chargers | 119 |
| 9.5.5 | Medium Voltage Switchgear | 119 |
| 9.5.6 | Automatic Transfer Switches | 119 |
| 9.6 | Project Drawings List | 120 |
| 9.7 | The SAS Engineering Process from the Standard IEC 61850 Perspective | 120 |
| | Further Reading | 120 |
| 10 | Communication with the Remote Control Center | 123 |
| 10.1 | Communication Pathway | 123 |
| 10.2 | Brief on Digital Communication | 123 |
| 10.2.1 | The OSI Reference Model | 124 |
| 10.2.2 | The IEC Enhanced Performance Architecture Model | 127 |
| 10.3 | Overview of the Distributed Network Protocol (DNP3) | 127 |
| 10.3.1 | The Device Profile Document | 128 |
| 10.3.2 | The DNP3 Implementation Level | 128 |
| 10.3.3 | The DNP3 Implementation Document | 128 |
| | Further Reading | 129 |
| 11 | System Attributes | 131 |
| 11.1 | System Concept | 131 |
| 11.2 | Network Topology | 132 |
| 11.3 | Redundancy Options | 134 |
| 11.4 | Quality Attributes | 135 |
| 11.4.1 | System Reliability and Availability | 135 |
| 11.4.1.1 | Considerations of the Standards | 136 |
| 11.4.1.2 | Example of an Availability Calculation | 136 |
| 11.4.2 | System Maintainability and Security | 138 |

| | | |
|-----------|---|------------|
| 11.5 | Provisions for Extendibility in Future | 138 |
| 11.6 | Cyber-Security Considerations | 139 |
| 11.7 | SAS Performance Requirements | 139 |
| | Further Reading | 140 |
| 12 | Tests on SAS Components | 141 |
| 12.1 | Type Tests | 141 |
| 12.1.1 | <i>Basic Characteristics Tests</i> | 141 |
| 12.1.2 | <i>Functional Tests</i> | 143 |
| 12.2 | Acceptance Tests | 143 |
| 12.3 | Tests for Checking the Compliance with the Standard IEC 61850 | 144 |
| | Further Reading | 144 |
| 13 | Factory Acceptance Tests | 145 |
| 13.1 | Test Arrangement | 145 |
| 13.2 | System Simulator | 145 |
| 13.3 | Hardware Description | 145 |
| 13.4 | Software Identification | 146 |
| 13.5 | Test Instruments | 146 |
| 13.6 | Documentation to be Available | 146 |
| 13.7 | Checking System Features | 146 |
| 13.7.1 | <i>Checking Basic Features</i> | 147 |
| 13.7.2 | <i>Checking Power Circuit Screens</i> | 147 |
| 13.7.3 | <i>Checking the SAS Scheme Screen</i> | 148 |
| 13.7.4 | <i>Checking Reports Screens (Each Type)</i> | 148 |
| 13.7.5 | <i>Checking Measurement Screens</i> | 148 |
| 13.7.6 | <i>Checking Time Synchronization Facilities</i> | 149 |
| 13.7.7 | <i>Checking of Self-Supervision Functions</i> | 149 |
| 13.7.8 | <i>Checking Peripheral Devices</i> | 149 |
| 13.7.9 | <i>Checking Collateral Subsystems</i> | 149 |
| 13.7.10 | <i>Checking Redundant Functionalities</i> | 149 |
| 13.8 | Planned Testing Program for FAT | 150 |
| 13.8.1 | <i>System Behavior in an Avalanche Condition</i> | 150 |
| 13.8.2 | <i>System Performance</i> | 150 |
| 13.8.3 | <i>Test of the Time Synchronization Mechanism</i> | 152 |
| 13.8.4 | <i>Test of Event Buffer Capability</i> | 152 |
| 13.8.5 | <i>Interlocking Logics</i> | 152 |
| 13.8.6 | <i>Synchronization Features</i> | 152 |
| 13.8.7 | <i>Operational Logic of Transfer Switch</i> | 152 |
| 13.8.8 | <i>Tests on the Communication Link for Technical Service</i> | 152 |
| 13.9 | Nonstructured FATs | 153 |
| 13.10 | After FATs | 153 |
| | Further Reading | 153 |
| 14 | Commissioning Process | 155 |
| 14.1 | Hardware Description | 156 |
| 14.2 | Software Identification | 157 |