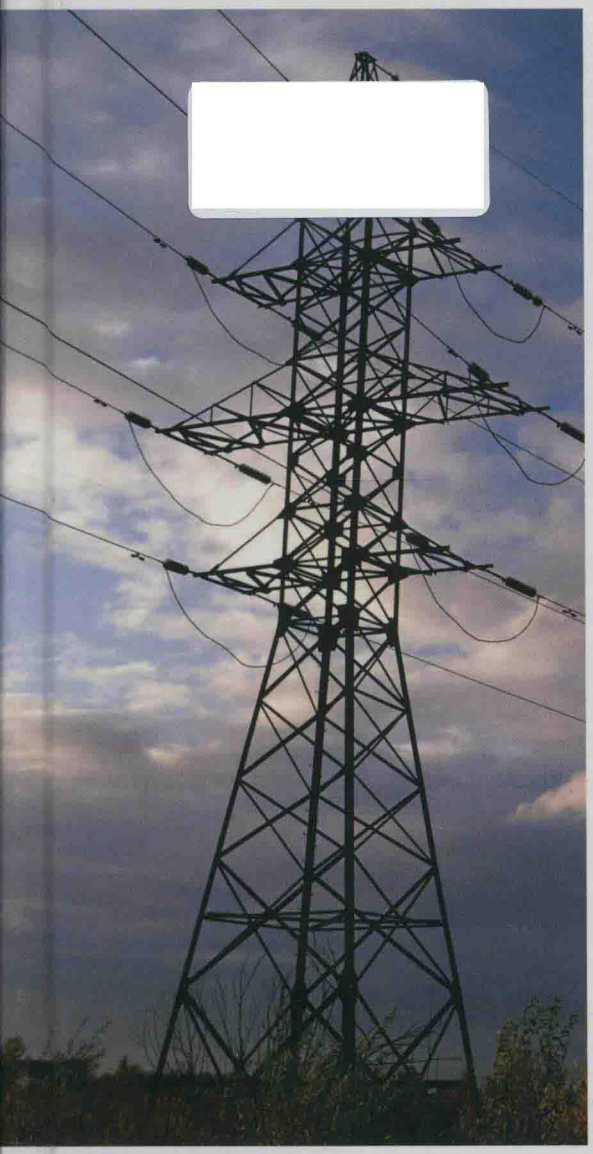
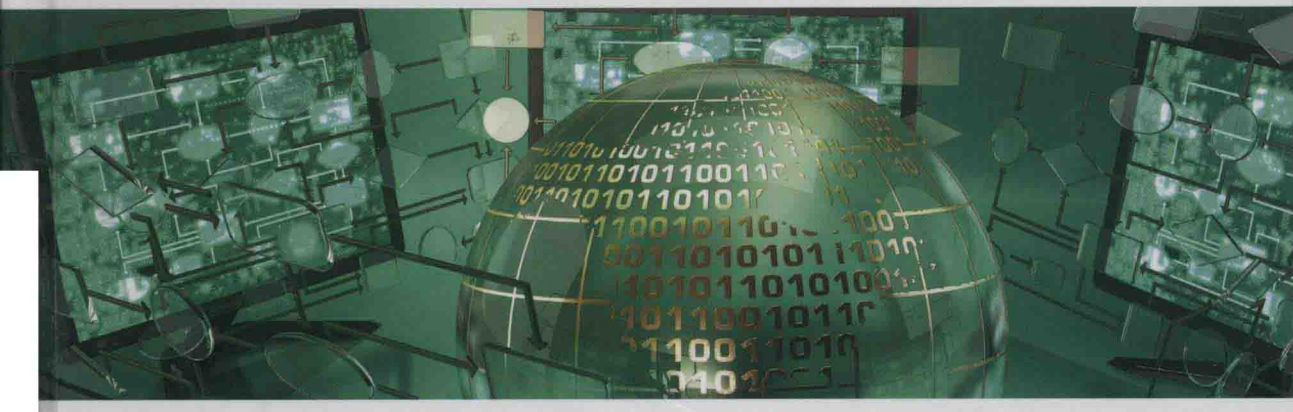


Substation Automation Systems

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

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.

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

1 2016

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 contributional 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	Disconnector
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
SF6	Sulfur hexafluoride
SLD	Single line diagram
SOE	Sequence of events
SV	Sampled values
SVC	Static var compensator
VT	Voltage transformer

Contents