



**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTRICAL POWER AND MACHINE DEPARTMENT**

**Wireless Transformer Substation Automation Using Zigbee
Technology**

By

Eng. Mohamed Ibrahim Sabry Sayed Mohamed Ahmed Mohsen

A thesis submitted to the Faculty of Engineering-Ain Shams University in partial
fulfillment of the requirement of the M.Sc. degree in Electrical Power and Machines
Engineering

Under supervision of

Prof. Dr. Hamdy Saleh Khalil El-Gohare

Electrical Power and Machine Department
Faculty of engineering, Ain shams university

Dr. Mohamed Abd El-Aziz Hassan Abd El-Rahman

Electrical Power and Machine Department
Faculty of engineering, Ain shams university

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APPROVAL SHEET

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Approved by

Name

Signature

Prof. Dr. Hamdy Saleh Khalil El-Gohare

Electrical Power and Machine Department
Faculty of engineering, Ain shams university

.....

Dr. Mohamed Abdel-Aziz Hassan Abdel-Rahman

Electrical Power and Machine Department
Faculty of engineering, Ain shams university

.....

Examiners Committee

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Engineering

Name

Signature

Prof. Dr. Mohamed Abdel-Alim El-Hadidy

Consultant for Egyptian Electrical Holding Co.

.....

Prof. Dr. Hamdy Saleh Khalil El-Gohare

Electrical Power and Machine Department

Faculty of engineering, Ain shams university

.....

Prof. Dr. Yasser Gamal El-Deen Hegazy

Dean of Faculty of information Engineering & Technology

German University in Cairo.

.....

Dr. Mohamed Abdel-Aziz Hassan Abdel-Rahman

Electrical Power and Machine Department

Faculty of engineering, Ain shams university

.....

Statement

This dissertation is submitted to Ain Shams University for the degree of M.Sc. in Electrical Power Engineering.

The Author has carried out the work included in this thesis at the Department of Electrical Power Engineering, Faculty of Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

Name: Mohamed Ibrahim Sabry

Signature:

Date: -2013

Dedication

To my Family.

Acknowledgement

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Abstract

Power systems have experienced many developments and changes over decades. However recent development in Smart Grid and dispersed generation are pushing quickly towards developing unusual solutions to the grid control allowing the grid to optimize itself. Also new incomings to Power system like electric vehicles, and home automation requires new dynamic network topologies. These topologies should allow dynamic loads like EV to be integrated to power system grid automation for better load distribution.

The main motive to this thesis is to propose model for substation automation based on Wireless sensor networks. Moreover message delays will be studied and improved to cope with delay demand which is dead lock for Substation Automation. This will help to solve problem facing expansion of smart grid, which is cable laying costs and effort. This model will provide many parallel paths for communication in electromagnetic harsh environment like power stations. Also it will allow integration of dynamic loads like EV to power systems.

This Substation Automation model based on IEC 61850 standard and Zigbee wireless sensor networks technology is selected to solve these problems. IEC 61850 provides standardized data structure for electrical substation functions. This allows interoperability between power grid equipment. Zigbee provides communication over wireless sensor networks that allows fast and easy deployment of the equipment, unlimited network expansion capabilities, dynamic topologies which is suitable for EV, network self heal capabilities and low cost.

The objective is to measure message delays when this proposed model is used. Further more, these delays will be compared to IEC 61850 requirements. The methodology followed in this study is Monte Carlo simulation as substation events are generated randomly, not following definite pattern.

Therefore we simulate proposed communication in Different substation types described by IEC61850 to compare results with IEC61850 requirements. First case study, we simulate D1 substations using Zigbee constant deactivation periods mode. The same simulation is repeated for many cases for D1 substation by changing no. channels. In the next step we used same method for larger substations D2, D3, T1, and T2. After that Zigbee Monitoring mode is used for all types of substations. Monitoring methodologies for Substation equipment will be developed for equipment in Substations.

Results show that IEC 61850 requirements are fulfilled. Zigbee Monitoring mode is more suitable for all substation types. Monitoring mode allows reduction of communication traffic on channels. Constant deactivation period can only be used for small substations like D1 and T1. The deactivation period should be less than 60 msec. to fulfill IEC 61850 requirements. Also multiple channels should be used.

Finally IEC 61850 requirements were fulfilled. Also results show that Monitoring Mode is most efficient for Substation Automation.

Table of contents

TABLE OF CONTENT.....	VI
LIST OF FIGURES.....	IX
LIST OF TABLES	XI
LIST OF ABBREVICATIONS.....	XII
LIST OF DEFINITIONS.....	XIII
(1) INTRODUCTION.....	1
1.1 Substation Automation (SA)	1
1.2 Historical Background.....	1
1.3 Basic Levels and specifications of SA Systems	2
1.4 Systems Elements	3
1.4.1 Intelligent Electronic devices (IED)	4
1.4.2 Bay Controller	4
1.4.3 Human Machine Interface	5
1.4.4 Communication Buses	5
1.4.5 Link to central	5
1.5 Motivation for thesis	5
1.6 Objective of thesis	6
1.7 Thesis Outline	7
(2) International Standard IEC 61850	10
2.1 Introduction	10
2.2 Why IEC 61850 is different	11
2.3 Structure of IEC 61850	12
2.4 Using IEC 61850	13
2.5 Logical interfaces between SA system levels	13
2.5.1 Process level	15
2.5.2 Bay level	15
2.5.3 Station level	15
2.6 Data Modeling and services	16
2.6.1 Abstract Communication Service Interfaces (ACSI)	17
2.6.2 Common data classes	17
2.6.3 Compatible logical node classes	17
2.7 Abstract Communication Service Interfaces (ACSI)	17
2.7.1 Basic Information Model	18
2.7.1.1 Server	18
2.7.1.2 Logical Device (LD)	18
2.7.1.3 Logical Node (LN)	19
2.7.1.4 Data	19
2.7.2 Services and Parameters	19

2.8 Logical Nodes	20
2.8.1 Logical node groups and names	20
2.8.2 Logical Nodes and function implementation	21
2.8.3 Logical nodes Syntax and semantics	23
2.9 Physical device structure	24
2.10 Types of substation	26
2.10.1 Type D1 Small Distribution Substation	26
2.10.2 Type D2 Medium Distribution Substation	26
2.10.3 Type D3 Large Distribution Substation	27
2.10.4 Type T1 Small Distribution Substation	28
2.10.5 Type T 2 Large Distribution Substation	29
2.11 Summary.....	30

(3) Wireless Sensor Networks (WSN)31

3.1 Introduction.....	31
3.2 Topologies of wireless sensor networks	32
3.2.1 Star Topology.....	32
3.2.2 Mesh Topology	33
3.2.3 Hybrid Topology.....	33
3.3 Wireless sensor networks famous technologies.....	35
3.3.1 Wireless HART.....	35
3.3.2 Z Wave.....	35
3.3.3 Wibree.....	36
3.3.4 6LowPAN.....	36
3.3.5 EnOcean.....	36
3.3.6 Zigbee.....	36
3.4 Why Zigbee?	37
3.5 Zigbee.....	38
3.5.1 Zigbee protocol stack.....	39
3.5.1.1 Physical Layer.....	40
3.5.1.2 Medium Access control and CSMA/CA Algorithm.....	40
3.5.1.3 Application Layer.....	45
3.5.1.4 Network Layer.....	46
3.5.2 Zigbee Device types.....	46
3.5.2.1 Coordinator.....	46
3.5.2.2 Router.....	46
3.5.2.3 End Devices.....	46
3.5.3 Zigbee Cluster Libraries.....	47
3.5.3.1 Client Server Model.....	47
3.5.3.2 ZCL Functional Domain.....	48
3.5.4 Application Profiles.....	51

3.5.5 Zigbee Security.....	53
3.5.5.1 Security Key.....	54
3.5.5.2 Security Modes.....	55
(4) WSN Application in Power Systems.....	56
4.1 Introduction.....	56
4.2 Logical Nodes in IED'S.....	56
4.3 IED behavior.....	58
4.4 Data Mapping In Zigbee.....	60
4.5 Physical Medium Selection.....	61
4.6 Payload calculations.....	64
4.6.1 Data frames.....	68
4.6.2 Inter frame periods.....	69
4.6.3 Message duration calculations.....	69
4.7 Methodology of Results Assessment.....	71
4.7.1 Type 1 Fast message.....	71
4.7.2 Type 2 Medium speed messages.....	71
4.7.3 Type 3 Low speed Messages.....	72
4.8 Case studies.....	73
4.8.1 D1 Small Distribution Substation.....	73
4.8.2 D2 Medium Distribution Substation (Monitoring Mode).....	90
4.8.2.1 Breaker IED.....	91
4.8.2.2 Isolator IED.....	93
4.8.2.3 Transformer IED.....	95
4.8.2.4 Relay IED.....	96
4.8.2.5 D2 results.....	96
4.8.3 D3 Substation.....	99
4.8.4 T1 Substation	100
4.8.5 T2 Substation	100
(5) Conclusion and future work.....	101
5.1 Conclusion.....	101
5.2 Future work	102
 Appendices	
(A) Published paper.....	103
(B) Programs.....	109
References.....	136

List of Figures

Figure	Page
1.1 Basic Levels in Substation Automation	2
1.2 Main substation automation elements	4
2.1 Substation levels and logical Interfaces	15
2.2 Data Modeling and services levels	16
2.3 Basic Information model	18
2.4 ASCI conceptual class diagram	19
2.5 Different Logical Node allocation for same function	22
2.6 Physical device Structure	25
2.7 Allocation of LN in different physical devices	25
2.8 Type D1 substation	26
2.9 Type D2 substation	27
2.10 Type D3 substation	28
2.11 Type T1 substation	28
2.12 Type T2 substation	29
3.1 Star topology.....	32
3.2 Mesh Network Topology.....	33
3.3 Hybrid network topology.....	34
3.4 Different communication paths in hybrid network.....	34
3.5 range extension through hybrid networks.....	35
3.6 Zigbee protocol Stack.....	39
3.7 Super frame structure.....	41
3.8 CSMA/CA Algorithm.....	44
3.9 Client server model.....	48
3.10 Example for Measurement and sensing clusters.....	51
3.11 Forming of application profiles from cluster libraries.....	52
4.1 Basic Information Model.....	58
4.2 Example for SA.....	59
4.3 Data mapping in Zigbee.....	60
4.4 Channels of 2.4 GHz Spectrum.....	61
4.5 Dynamic Network Topologies.....	62
4.6 Unslotted CSMA/CA.....	63
4.7 Pay load calculation form LN, CDC and Basic types.....	64
4.8 Data Frame in Zigbee.....	68
4.9 Inter frame spacing.....	69
4.10 D1 substation example.....	73
4.11 D1 substation example.....	74
4.12 Effect changing deactivation period on orphan node % (1 channel)	76
4.13 Effect of changing deactivation period on max. delay (1 channel)	77

4.14 Message delay histogram for 1 channel and 2 sec. deactivation period.....	77
4.15 Message delay histogram for 1 channel and 1 sec. deactivation period	78
4.16 Message delay histogram for 1 channel and 0.75sec. deactivation period	78
4.17 Message delay histogram for 1 channel and 0.1sec. deactivation period	79
4.18 Orphan node percent for variable no. of channels and deactivation periods.....	80
4.19 Deactivation period effects on Max. delay (2 channels).....	80
4.20 Message delay histogram for 2 channel and 0.1sec. deactivation period	81
4.21 Effect of changing deactivation period on orphan node % (3 channel)	82
4.22 Effect of changing deactivation period on max. delay (3 channel)	82
4.23 Message delay histogram for 3 channel and 0.1sec. deactivation period	83
4.24 Effect of changing deactivation period on orphan node % (5 channel)	84
4.25 Effect of changing deactivation period on max. delay (5 channel)	84
4.26 Message delay histogram for 5 channel and 0.1sec. deactivation period	85
4.27 Orphan node percent for variable no. of channels and deactivation periods	86
4.28 Deactivation period effects on Max. Delay	87
4.29 time delay distribution for deactivation period (1 Sec).....	87
4.30 D2 substation	89
4.31 Communication behavior of Transformer IED.....	91
4.32 Communication behavior of relay IED.....	93
4.33 Communication behavior of Transformer IED	94
4.34 Communication behavior of Relay IED	95
4.35 Orphan node percent to No. of nodes per channel	96
4.36 Delay Distribution for 5 nodes per channel (monitoring mode)	97
4.37 Delay Distribution for 10 nodes per channel (monitoring mode)	98
4.38 Delay Distribution for 20 nodes per channel (monitoring mode)	98
4.39 Delay Distribution for 40 nodes per channel (monitoring mode)	99

List of Tables

Table	Page
2.1 Using IEC 61850	13
2.2 Logical Node Groups	21
2.3 Logical Node overvoltage Syntax and semantics	23
3.1 comparison between frequencies bands in Zigbee	40
3.2 Zigbee cluster library	48
3.3 General functional domain clusters	49
3.4 Measurement and sensing functional domain clusters	50
4.1 Frequencies of IEEE 802.15.4 comparison.....	61
4.2 Gen Logical Node.....	65
4.3 Instance Data Class.....	66
4.4 Basic data types.....	68
4.5 D1 Substation Simulation results for 1 channel different deactivation periods.....	76
4.6 D1 Substation Simulation results for 2 channel different deactivation periods.....	76
4.7 D1 Substation Simulation results for 3 channel different deactivation periods.....	77
4.8 D1 Substation Simulation results for 5 channel different deactivation periods.....	77
4.9 Simulation results for monitoring mode.....	97

List of Abbreviations

ACSI	Abstract Communication Service Interface
APS	Application Support Sublayer
APSD	Application Support Data Entity
APSM	Application Support Management Entity
AIB	Application Support Information Base
AMR/AMI	Advanced Metering Reading/ Advanced Metering Infrastructure
CAP	Contention Access Period
CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
CFP	Contention Free Period
CT	Current Transformer
CDC	Common Data Classes
EV	Electric Vehicle
FDIR	Fault Detection Identification and Recovery
GTS	Guaranteed Time Slot
GW	Gateway
HMI	Human Machine Interface
HAN	Home Area Network
I & C	Instrumentation and Control
I/O	Input/ Output
IEC	International Electrical Committee
IED	Intelligent Electronic Device
LN	Logical Node
LD	Logical Device
M	Mandatory
MAC	Medium Access Control
NCC	Network Control Center
O	Optional
PAN	Personal Area Network
PT	Potential Transformer
PHY Layer	Physical Layer
RTU	Remote Terminal Unit
SA	Substation Automation
SAP	Service Access Point
VVO	Voltage VAR Optimization
WSN	Wireless sensor networks
ZDO	Zigbee Device Object
ZCL	Zigbee Cluster Library