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

# Wireless Transformer Substation Automation Using Zigbee Technology

**By**

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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

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Cairo 2013

APPROVAL SHEET

For the M.Sc. thesis

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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.

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Date: -2013

# Dedication

To my Family.

Acknowledgement

Thanks to Allah before and after, who blessed me with dedicated supervisors, and supported me until the conclusion of this work.

The author is indebted to many people for their advice, assistance and encouragement while advising in his thesis, especially Prof. Dr. Hamdy El-Gohare, Professor of electrical Power and machines Engineering Dept., Faculty of Engineering, Ain Shams University. The Author also wishes to express his deepest thanks to Dr. Mohamed Abdel-Aziz, Associate Prof. of electrical power and machines engineering, Ain Shams University, for his supervision, valuable comments and suggestions. The Author also wishes to express his deepest thanks to Dr. Khaled El Bahrawy, Chair man of El-Bahrawy consulting group, for his valuable discussions, guidance, support, encouragement and supervision throughout the course of this research.

Acknowledgment is extended also to all staff members and colleagues in Electrical Power and Machines Dept.,Ain Shams University.

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.

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## List of Abbreviations

| | |
|---|---|
| ACSI | Abstract Communication Service Interface |
| APS | Application Support Sublayer |
| APSDE | Application Support Data Entity |
| APSME | 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 |