
**UNIVERSITI PUTRA MALAYSIA**

***ROBUST COMMUNICATION IN DIFFERENTIAL RELAY PROTECTION USING WIRELESS TECHNIQUE***

**MALIK QASIM BADAR**

# ROBUST COMMUNICATION IN DIFFERENTIAL RELAY PROTECTION USING WIRELESS TECHNIQUE

**By**

**MALIK QASIM BADAR**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science**

**February 2015**

## DEDICATION

*This thesis is especially dedicated to my parents, brother, sisters and friends.*

## ABSTRACT

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

**ROBUST COMMUNICATION IN DIFFERENTIAL RELAY PROTECTION USING WIRELESS TECHNIQUE**

By

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**February 2015**

**Chairman: Mohammad Lutfi Othman, PhD, Ir**

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The traditional power system protection performance has been constrained by the manufacturers' specified limit errors of current transformers' CTs burden. The conventional hardwire communication between CTs and protective relays has imposed difficulties in selecting the best possible protective relay devices to be used with the intended CTs so as not to overburden and saturate the CTs. Any saturation on the part of the CTs will incur errors on the measurements and tripping decisions made by the protective relays. In order to address this problem, a study has been carried out to evaluate the performance of a wireless differential transformer protection using Wireless Fidelity (Wi-Fi) that has done away with the traditionally hardwired copper communication medium of incoming measured voltages and currents of relay from the CTs. This approach is envisaged to be able to minimize the CT burden due the absence of signaling copper cables, reduce CT saturation and, importantly, performs a reliable protection system of the differential protective relay. The works involved are simulating transformer power quantities and wireless transmitted signals using the National Instrument data acquisition device (NI-DAQ) NI 9227 and modelling a transformer differential protection using National Instrument graphical programming tool LabVIEW. The results from the experiment demonstrate that the wireless transformer differential protection is able to avoid CT overburdening and saturation and, hence allow a more efficient protection operation performed by the relay. The fact that it is wireless, the cost of implementation can also be reduced and the problems of electromagnetic interference can be minimized.

## ABSTRAK

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

**KOMUNIKASI TEGUH DALAM PERLINDUNGAN GEGANTI KEBEZAAN MENGGUNAKAN TEKNIK TANPA WAYAR**

Oleh

**MALIK QASIM BADAR**

**February 2015**

**Pengerusi: Mohammad Lutfi Othman, PhD, Ir**

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Prestasi perlindungan sistem kuasa tradisional telah dikekang oleh 'ralat had tertentu pengubah semasa pengilang beban (beban CT). Komunikasi hardwire konvensional antara CT's dan geganti pelindung telah mengenakan kesukaran dalam memilih peranti mungkin geganti yang terbaik untuk digunakan dengan CT's dimaksudkan supaya tidak membebankan dan menepukan CT's. Sebarang tepu di pihak CT's akan menanggung kesalahan pada ukuran dan keputusan tersandung membuat geganti perlindungan. Dalam usaha untuk menangani masalah ini, satu kajian telah dijalankan untuk menilai prestasi perlindungan pengubah kebezaan tanpa wayar menggunakan Wireless Fidelity (Wi-Fi) yang telah dihapuskan tradisional terdawai keras (tembaga) medium komunikasi kuantiti masuk diukur (iaitu voltan dan arus) geganti dari CT's. Pendekatan ini dijangka dapat mengurangkan beban CT kerana ketiadaan kabel tembaga isyarat, mengurangkan CT tepu dan yang penting, melaksanakan sistem perlindungan dipercayai geganti pengkamiran perlindungan. Kerja-kerja yang terlibat adalah simulasi kuantiti kuasa pengubah dan wayarles isyarat dihantar menggunakan peranti Instrumen Nasional perolehan data (NI-DAQ) NI 9227 dan model perlindungan pengubah kebezaan menggunakan Instrumen Nasional alat pengaturcaraan grafik LabVIEW. Hasil daripada eksperimen menunjukkan bahawa perlindungan pengubah pengkamiran wayarles mampu mengelakkan dari overburdening dan tepu CT's dan, dengan itu membolehkan operasi perlindungan yang lebih cekap dilakukan oleh geganti. Hakikat bahawa ia adalah tanpa wayar, kos pelaksanaan juga dapat dikurangkan dan masalah gangguan elektromagnetik boleh dikurangkan.

## ACKNOWLEDGEMENTS

I would like to express the deepest gratitude to my supervisor, Ir Dr. Mohammad Lutfi Othman, for his supports regarding research. His continued advice, guidance and encouragement led me to the right way. I would like to extend my appreciation to other committee members, Assoc. Prof. Dr. Mohd. Amran b. Mohd. Radzi and Dr. Noor Izzri b. Abd. Wahab, for their effective advices during my research. I am also very thankful to all the researchers and lab mates at the Faculty of Engineering, UPM who have always helped and assisted me in my research.

I am truly grateful to my Mother 'Naheed Kousar' and father 'Badar ul Islam' for their immeasurable love and care. They have always encouraged me to explore my potential and pursue my dreams. I would express a deep sense of gratitude to my parents, for supporting and keeping me motivated throughout my research. She overcame serious difficulties when we were far from each other during my study. I would also like to thank my father, brothers, sisters, Su, tutu, thaili wala and friends for their everlasting encouragement and supports

I certify that a Thesis Examination Committee has met on 5 February 2015 to conduct the final examination of Malik Qasim Badar on his thesis entitled "Robust Communication in Differential Relay Protection using Wireless Technique" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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**Declaration by Graduate Student**

I hereby confirm that:

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| CT | Current Transformer |
| PT | Power Transformer |
| IOP | Operational Current |
| IRT | Restraint Current |
| AWG | American Wire Gauge |
| PLC | Power Line Carrier |
| LED | Light Emitting Diode |
| PSTN | Public Switch Telephone Network |
| Wifi | Wireless Fidelity |
| NI | National Instrument |
| LABVIEW | Laboratory Virtual Instrument Engineering WorkBench |
| PSCAD | Power System Computer Aided Design |
| EMTDC | Electro Magnetic Transient for DC |
| MATLAB | MATrix LABoratory |
| IP | Internet Protocol |
| GUI | Graphical User Interface |
| FPGA | Field Programmable Gate Array |
| DAQ | Data AcQuisition |
| AI | Analog Input |
| AO | Analog Output |
| USB | Universal Serial Bus |
| ADSL | Asymmetric Digital Subscriber Line |
| ADC | Analog to Digital Converter |

# CHAPTER 1

# INTRODUCTION

Transformer is an important device in a power system. Hence, its protection is also equally important. The primary objective should be to detect faults and minimize danger associated with it. Different types of faults can occur in a transformer for which communication medium plays an important role to inform relay to generate tripping signal.

Recent studies and development in power system network have solved many problems but some of them still need to be addressed effectively. Today's researchers should try to address to reduce all problems and make power systems work efficiently and reliably. One of the major issue is the burden of current transformer in transformer differential protection. Therefore, there is a need to develop systems which can help reducing burden of current transformer and effectively solve issues like saturation and selection of relay. Moreover, the designed systems should also be reliable, secure and efficient.

## 1.1 Importance of communication medium

In protective relaying, transmission of monitored data can be from different sources like generator, transformer or any device to relay. This monitored data helps relay to differentiate between a fault and normal condition. Communication medium plays a vital role. In one hand, it is an essential part for a power system and on the other it is also important for interfacing between different types of hardware. In a power system, communication medium acts as heart of system that needs to work continuously while transmitting data from one place to another. Researchers are actively making efforts on making communication systems more effective, reliable, secure and fast.

## 1.2 Performance Issues in Protective Relay

Inaccurate, slow, insensitive detection and isolation are strongly dependent on technicality of protective relays. These factors strongly affect the performance of protective relays. Some issues are mentioned below.

- Distorted signals of secondary side of transformer during transient in CT saturation (Kojovic & Day, 1999).
- Power system network complexity and complexity of wires (Chan & Snider, 2000).
- Protective devices can be exposed to extreme fault due to saturation (Kojovic & Day, 1999).
- Connecting wire resistances play a vital role in CT burden and need to be placed CTs closed to relay (Kojovic & Day, 1999)..

- Greater is the tendency of the current transformer to saturate, if burden impedance is increasing (David H & WSCC group, 1989).
- Impedances of equipment attached are very high (Lee, Jung, Kim, & Baek, 1999).
- Communication loss issue that leads to channel delay, noise, interruption fading, synchronization error (e.g. differential relay), etc. in relay protection. (Voloh, Kasztenny, & Campbell, 2001).

## 1.3 The Problem Statement

Power system protection performance has been constrained by the manufacturers' specified limit errors of current transformers' burden (CT burden) as mentioned in section 1.2. The conventional hardwire communication between CTs and protective relays have imposed difficulties in selecting the best possible protective relay devices to be used with the intended CTs so as not to overburden and saturate the CTs. Any saturation on the part of the CTs will acquire errors on the measurements and cause tripping decisions made by the protective relays (Powell, 1979) (Sawko, 2008). Former wire based communication medium like optical fiber cause error in synchronization and also a costly solution to implement with less issues of electromagnetic interference.

## 1.4 Objectives of Research

In order to address the above problems, a study has been carried out to develop and evaluate the performance of a wireless differential transformer protection using Wireless Fidelity (Wi-Fi).

- Provide an alternative to the traditionally hardwired (copper) communication medium of incoming measured quantities of relay from the CTs that is demonstrably efficient and highly usable.
- Given methodology should minimize the CT burden due the absence of signaling copper cables, reduce CT saturation and, importantly, perform a reliable protection system of the differential protective relay.

## 1.5 Scope of Research

This study aims to address the performance of a wireless differential transformer protection using Wireless Fidelity (Wi-Fi) communication medium of incoming measured quantities (i.e. voltages and currents) of relay from current transformers (CT's). More specifically this approach will be developed to minimize the CT burden due the absence of signaling copper cables, reduce CT saturation and gives reliable protection system of the differential protective relay. From within the domain of performance, the scope of the study is limited to evaluate the proposed system performance of conventional differential protection systems. The work will involve simulating transformer power quantities and the wireless transmitted signals using the

National Instrument data acquisition device (NI-DAQ) NI 9227 and modeling a transformer differential protection using the National Instrument graphical programming tool LabVIEW.

## 1.6 Contributions of Research

Contributions of this study are a mirror of the objectives discussed above. More specifically, this study involves simulating transformer power quantities and the wireless transmitted signals using National Instrument data acquisition device (NI-DAQ) NI 9227 and modelling a transformer differential protection using the National Instrument graphical programming tool LabVIEW.

The results from the experiment demonstrate that the wireless transformer differential protection is able to reduce overburdening and saturating the CTs and, hence allow a more efficient protection operation performed by the relay. Moreover, the fact that it is wireless, the cost of mass implementation will also be reduced and the problems of electromagnetic interference will be minimized.

## 1.7 Limitation of Research

This work is done in the National Instrument library (NI-AIN) having limited resources because of the huge cost associated with buying a differential relay and acquiring a real transformer.

## 1.8 Thesis Layout

Chapter 1 (introduction), provides an insight on necessity of protective relay performance analysis, problems and proposed solution, relay operations and scope of research.

Chapter 2 (literature review), reviews different faults, problems in CT and differential relay, different issues in using differential protection, drawback of using wires, and different medium of communication in protective relaying. It also highlights the advantages and disadvantages of different medium of communications.

Chapter 3 (Methodology), discusses the steps in achieving the stated research objectives defined for this research. It covers the implementation steps in detail and the expected results.

Chapter 4 (Result and Discussion), covers details of overcurrent fault that can occur during operation of relay, small error and behavior of circuit breaker response in simulation and hardware. The results are supported with relevant figures, tables and discussions.

Chapter 5 (Conclusion), concludes the discussion with comments on results achieved by implementing the proposed technique based on both simulation and hardware, also discussed future aspects of proposed process.

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