A Communication Method for Remote Control of Grid-tied Converters

Presenter
K. A. T. Lasagani

Supervisors
Dr. Tariq Iqbal
Dr. George Mann

October 31, 2017
Outline

1. Motivation
2. Introduction
3. low cost, long range
   - Range Testing
   - Evaluation
4. Develop LoRa
   - Inverter Side
   - Server Side
   - Evaluation
5. Reliability Analysis
   - Evaluation
6. Conclusion
Motivation

- Communication is a key factor in a SCADA system.
- Failure of the communication link can cause loss of data and loss of control over the system.
Motivation

K. A. T. Lasagani

A Communication Method for Remote Control of Grid-tied Converters
Introduction

Wired Communication
- Power Line Communication
- Digital Subscriber Lines
- Optical-Fibre Communication

Wireless Communication
- Cellular network communication
- WIFI
- Blue-tooth
Comparison of wireless technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Service</th>
<th>Data Rate</th>
<th>Coverage</th>
<th>Spectrum</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular</td>
<td>Data</td>
<td>Low-Moderate</td>
<td>Large</td>
<td>2GHz</td>
<td>Operating cost</td>
</tr>
<tr>
<td>LTE(4G)</td>
<td>Data</td>
<td>High</td>
<td>Large</td>
<td>1.7GHz-2.6GHz</td>
<td>Operating cost</td>
</tr>
<tr>
<td>Wi-fi</td>
<td>Data</td>
<td>High</td>
<td>Small</td>
<td>2.4GHz</td>
<td>Operating cost</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Data</td>
<td>High</td>
<td>Very Small</td>
<td>2.4GHz</td>
<td>Low</td>
</tr>
<tr>
<td>RF</td>
<td>Audio, Data</td>
<td>Low</td>
<td>Small</td>
<td>300-400MHz</td>
<td>Low</td>
</tr>
<tr>
<td>LoRa</td>
<td>Data</td>
<td>Very Low</td>
<td>Large range</td>
<td>ISM band</td>
<td>Low</td>
</tr>
<tr>
<td>UHF/ VHF</td>
<td>Data</td>
<td>Very Low</td>
<td>Large range</td>
<td>UHF band</td>
<td>Low</td>
</tr>
<tr>
<td>Radio Type</td>
<td>Voice</td>
<td>Very Low</td>
<td>Large range</td>
<td>UHF band</td>
<td>Low</td>
</tr>
</tbody>
</table>

Low cost, long range?
Related Works

- Zhou et al. present a communication system using general packet radio service (GPRS) and code division multiple access (CDMA) wireless communication networks in SCADA system.

- M. Y Zhai et al. present the measurement results of channel properties of LV PLC systems after giving a general overview of the topologies for the typical LV distribution networks in China.

- Conti et al. proposes a method combining Bluetooth and GPRS to make a vehicle to vehicle communication protocol and to make a smart grid.
Research Objectives

Goal

Develop a low cost, long range, secure and reliable communication method for remote control of a grid-tied inverter

**Objective 1:** Identify a low cost, long range, a secure and reliable communication method

**Objective 2:** Develop the selected communication method regarding security and reliability.

**Objective 3:** Develop a model to analyze reliability of the developed communication method.
A low cost, long range, secure and reliable communication method

Four communication methods in three technologies were tested,

- Radio Teletype (Ham Radio)
- VHF/ UHF data modules
- Two types of LoRa
  - Dragino LORA
  - Libelium LORA
Long Range (LoRa)

- Low Power Wide Area Networking technology
- Introduced for IoT applications.
- Developed by Semtech and LoRa alliance
- Uses 915 MHz ISM band
- Following features,
  - Long range for communication
  - Low path loss
  - Good sensitivity
  - Good obstacle penetration
Radio Teletype

- Use Land Mobile Radio (LMR) networks data communication.
- Four ham radios have been used to get a full duplex communication link.
- Software: FLDIGI (Open source)
UHF / VHF data transmission

- Very high frequency band has been using for data communications.
- Two set of data radios made by Lensen are being used.
- Any serial interface can be used.
Range Testing
Comparison

**Table:** Comparison of Tested Open Source Wireless Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost (CAD)</th>
<th>Power (tx)</th>
<th>Range</th>
<th>Data Rate (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragino LoRa</td>
<td>55.00</td>
<td>100mW</td>
<td>220m</td>
<td>9600</td>
</tr>
<tr>
<td>Libelium LoRa</td>
<td>250.00</td>
<td>25mW</td>
<td>4.5km</td>
<td>9600</td>
</tr>
<tr>
<td>Ham Radio</td>
<td>140.00</td>
<td>5W</td>
<td>7.2km</td>
<td>50</td>
</tr>
<tr>
<td>1W Data Radio</td>
<td>120.00</td>
<td>1W</td>
<td>3.3km</td>
<td>1200, 2400</td>
</tr>
</tbody>
</table>
Develop LoRa in terms of security and reliability

Issues with LoRa

- **Security**: No end to end encryption
- **Reliability**: Packet loss
Solution

- **Security**: encryption algorithm is developed and embedded in the Arduino.
- **Reliability**: local storage is added with a self data cleaning algorithm.

1. [https://www.lightwell.eu/fr/portfolio/lora/](https://www.lightwell.eu/fr/portfolio/lora/)
Inverter Side

- TFT Display
  - Display and SD Card
  - SPI

- Arduino MEGA
  - Runs Data Processing Algorithm and Save data on SD Algorithm
  - UART

- RS232 Circuit
  - Communicates with the inverter
  - UART
  - SPI

- Arduino MEGA
  - Runs LoRa MEGA algorithm

- Libelium LoRa SX1272
Inverter Side

K. A. T. Lasagani

A Communication Method for Remote Control of Grid-tied Converters
Server Side

- Receive data from server side through LoRa and uploads to the server
- Send data received from the server to the inverter side
Evaluation

- Tested with an inverter developed by the UNB.
- Successfully communicated over 4.6 km.
Reliability modeling of the developed LoRa link

- Since this developed for a SCADA, measurement of the reliability of the system is important.
- There are analytical and simulation approaches to analyze the reliability.
- In this research fault tree and Monte-Carlo simulation based approach is used.
- Cetinkaya E. K. et. al. show that the typical unavailability is 0.01 for a SCADA and it is low mostly due to communication link failures.
Developed System

Model

Structure of the communication link
Communication system failure

- Failure in both LoRa link and the local storage will result in a total communication failure.
Results

\[ \text{Availability}(A) = \frac{\text{uptime}}{\text{uptime} + \text{downtime}} \quad (1) \]

- The analysis shows that the communication link has the lowest availability.
- Addition of a data storage parallel to the system has increased the availability of the system. From 0.994288 to 0.99946
Summary

To summarize, this thesis has made following key contributions in the field of SCADA systems by fulfilling all of the outlined research objectives,

- A framework has been developed to compare communication technologies.
- Improved a LoRa communication link regarding security and the reliability.
- Successfully demonstrated a combination of LoRa and PLC.
- Reliability model has been developed to analyze the reliability of the developed communication method.
Future Work

- Develop directional antenna.
- Develop a LoRaWAN network for Inverters
- Develop high secure encryption for low power processors
- Reduce power consumption of the developed system
Publications

Journal Articles

- Kumbalatara Arachchige, M. T. Iqbal, G. Mann, Data logging and control of a remote inverter using LoRa with local storage, submitted with IEEE Access 2017

Peer-reviewed Conference Articles


Abstract-reviewed Conference Articles

- Terashmila Lasagani, Tariq Iqbal, George Mann, Reliability Analysis of a Communication Link Developed for a SCADA System Using Monte-Carlo Simulation Approach, accepted to present at 26th IEEE NECEC conference 2017.

- Terashmila Lasagani, Tariq Iqbal, George Mann, Data Logging and Control of a Remote Inverter Using LoRa with A Local Storage, accepted to present at 26th IEEE NECEC conference 2017.

- Terashmila Lasagani, Tariq Iqbal, George Mann, the Best communication method for remote control of grid-tied converter for an energy storage system, presented at 25th IEEE NECEC conference 2016.

Poster presentations

- L. K. A. Terashmila, T. Iqbal and G. Mann, Data logging and control of a remote inverter using LoRa, Arduino, RS232 and SD card, Poster session presented at: NESTNet Technical Conference. 1st Annual conference. 21-22 July, 2017; Toronto, ON.
Acknowledgement

- Thesis supervisors
  - Dr. Tariq Iqbal
  - Dr. George Mann
- Funding sources
  - NSERC energy storage technology network (NESTNET).
  - School of Graduate Studies (SGS), Memorial University of Newfoundland, Canada.
- Dr. Liuchen Chang and his research group from the University of New Brunswick.
- Dr. Bala Venkatesh and his research group from the Ryerson University
- Staff of the Wind Energy Institute of Canada.
- Intelligent Systems (IS) lab research group.
- The faculty and the staff of Engineering, MUN.
- Family and friends.
THANK YOU