Faculdade de Engenharia da Universidade do Porto

Monitoring photovoltaic converters using Wireless Sensor Networks

—

Activity report

Vítor A. Morais

DRAFT VERSION

Programa Doutoral em Engenharia Electrotécnica e de Computadores

Supervisor: António P. Martins

June 14, 2017

Monitoring photovoltaic converters using Wireless Sensor Networks

—

Activity report

Vítor A. Morais

Programa Doutoral em Engenharia Electrotécnica e de Computadores

June 14, 2017

Contents

1 Introduction

This chapter presents the context, motivation and document structure of the activity report of monitoring photovoltaic converters using Wireless Sensor Networks.

1.1 Context and motivation of PhD

The railway system is responsible for 1.3% of entire European energy consumption, **?**. The discussion of the energy efficiency in railways is a grown topic due to its contribution to the global energy consumption.

The energy efficiency analysis and management requires a detailed mapping of the energy consumption/generation in the railway system.

This detailed mapping of the energy flows should include, not only the rolling stock level but also the traction substations and the auxiliary services.

The knowledge of all the load curves permits the load prevision, peak shaving and energy cost optimization for all global railway system.

1.2 Context and motivation of monitoring PV converters using WSN's

This activity report is inserted in the scope of a microgeneration project of the SYSTEC Research Unit. Figure 1 in attachment presents the main architecture of this project. Currently, several work has been done in this project to implement a monitoring subsystem. This work focuses on data collection from each power converter and also on its control by sending references and actions. At the moment of this proposal, no work has been done to implement the monitoring feature in the PV converters. This way, a wireless network implementation is proposed to monitor the PV power converters.

The PV converter uses a non-isolated high gain DC/DC topology and has a PIC32 microcontroller which implements a MPPT algorithm in the control loop. It is currently possible to connect a device with wireless capabilities to the PV power converter. The converter is able to provide power and data. The data collected from the monitoring device is sent to an aggregator node for post processing and data storage. Currently, several work has already been done to have a reliable wired data aggregator/concentrator (figure 2). This subsystem is also responsible for sending user commands to the power converters and presenting the user interface in a webpage remotely accessed via a web browser.

1.3 Document structure

This document is divided in 5 chapters, each of them incorporate the relevant subsections to present the subjects mentioned.

Table 1.1: Document structure

Chapter	Title
1	Introduction
2	System Specification
3	Development of Wireless Monitoring System
4	Results and Discussion
5	Conclusions and Future Work

2 System Specification

In this chapter, the system specification is defined, starting with the overview of the existing communication systems and defining the SRS. After that is made a market survey on the existing technologies and raised the protocols, standards and communication KPI's.

2.1 Overview of the existing communication system

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2.2 System Requirement Specification

In the attachment 1 is present the SRS document. This document uses the following structure (based on a template from Generic Ethernet Gateway (GWAY) developed by Chrysler Group LLC):

Introduction This part describes the purpose of the document, the scope and the context of the system/project where is implemented;

Overall Description In this part is described the system, it's objectives and features as well as some design and implementation constraints;

Specific requirements This part defines the specification of the requirements that the system must comply with;

Data Model and Description This part covers the definition of the system in UML diagrams and descriptions.

The definition of the system with this document allows the system specification according to the main goal of this activity: the development of a Wireless network to monitor existent PV power converters.

2.3 Market survey on wireless technologies

The market survey was conducted to cover recent technologies among manufacturers with enhanced market share.

2.3.1 Atmel – SAM R21 Xplained Pro Evaluation Kit

http://www.atmel.com/tools/atsamr21-xpro.aspx

The Atmel® SAM R21 Xplained Pro evaluation kit is a hardware platform to evaluate the ATSAMR21G18A microcontroller. Supported by the Atmel Studio integrated development platform, the kit provides easy access to the features of the Atmel ATSAMR21G18A and explains how to integrate the device in a custom design. The Xplained Pro MCU series evaluation kits include an on-board Embedded Debugger, and no external tools are necessary to program or debug the ATSAMR21G18A. The Xplained Pro extension kits offers additional peripherals to extend the features of the board and ease the development of custom designs.

In synthesis, this platform is based on a single chip solution that integrates in the same integrated circuit an ARM® Cortex®-M0+ processor and an integrated ultra-low-power 2.4GHz ISM band transceiver. It's relevance is on the ultra-low-power consumption (less that 70μA in active mode and less than 3.5μA in sleep mode).

Figure 2.1: SAM R21 Xplained Pro module.

2.3.2 CC1310 SimpleLink™ Sub-1 GHz Ultra-Low Power Wireless Microcontroller

http://www.ti.com/product/CC1310

The CC1310 is a member of the CC26xx and CC13xx family of cost-effective, ultra-low-power, 2.4-GHz and Sub-1 GHz RF devices. Very low active RF and microcontroller (MCU) current consumption, in addition to flexible low-power modes, provide excellent battery lifetime and allow long-range operation on small coin-cell batteries and in energy-harvesting applications.

The CC1310 device is the first device in a Sub-1 GHz family of cost-effective, ultra-low-power wireless MCUs. The CC1310 device combines a flexible, very low power RF transceiver with a powerful 48-MHz Cortex®-M3 microcontroller in a platform supporting multiple physical layers and RF standards. A dedicated Radio Controller (Cortex®-M0) handles low-level RF protocol commands that are stored in ROM or RAM, thus ensuring ultra-low power and flexibility. The low-power consumption of the CC1310 device does not come at the expense of RF performance; the CC1310 device has excellent sensitivity and robustness (selectivity and blocking) performance.

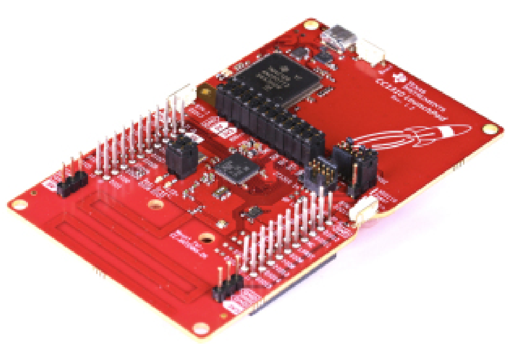

Figure 2.2: CC1310 evaluation board.

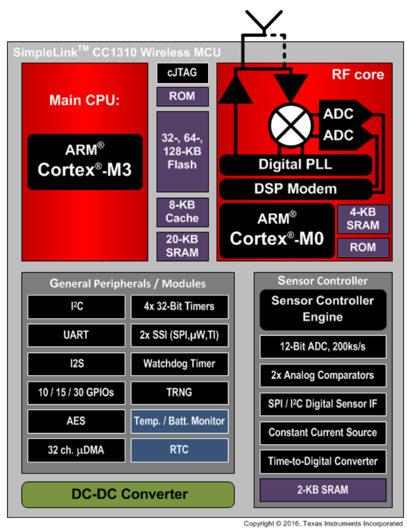

Figure 2.3: CC1310 chip architecture.

2.3.3 Adafruit Feather 32u4 Radio (RFM69HCW)

https://learn.adafruit.com/adafruit-feather-32u4-radio-with-rfm69hcw-module/overview

---

This Adafruit Feather 32u4 Radio (RFM69HCW) 900MHz microcontroller packet radio transceiver with built in USB and battery charging. 32u4 with a 900MHz radio module cooked in an Adafruit Feather. Great for making wireless networks that can go further than 2.4GHz 802.15.4 and similar, are more flexible than Bluetooth LE and without the high power requirements of WiFi. The 900MHz radio version can be used for either 868MHz or 915MHz transmission/reception. At the Feather, 32u4's heart is at ATmega32u4 clocked at 8MHz and at 3.3V logic. This chip has 32K of flash and 2K of RAM, with built in USB so not only does it have a USB-to-Serial program and debug capability built in with no need for an FTDI-like chip, it can also act like a mouse, keyboard, USB MIDI device, etc.

2.3.4 Adafruit Feather HUZZAH ESP8266

https://learn.adafruit.com/adafruit-feather-huzzah-esp8266/overview

---

This is the Adafruit Feather HUZZAH ESP8266 - our take on an 'all-in-one' ESP8266 WiFi development board with built in USB and battery charging. At the Feather HUZZAH's heart is an ESP8266 WiFi microcontroller clocked at 80 MHz and at 3.3V logic. This microcontroller contains a Tensilica chip core as well as a full WiFi stack. You can program the microcontroller using the Arduino IDE for an easy-to-run Internet of Things core. We wired up a high-quality SiLabs CP2104 USB-Serial chip that can upload code at a blistering 921600 baud for fast development time. It also has auto-reset so no noodling with pins and reset button pressings. The CP2104 has better driver support than the CH340 and can do very high speeds without stability issues.

2.3.5 ATxmega256A3U AT86RF233 ZigBit Module

http://www.atmel.com/pt/br/devices/ATxmega256A3U-and-AT86RF233-ZigBit-Wireless-Module.aspx

---

The Atmel ZigBit 2.4GHz ATZB-X0-256-3-0-C wireless system-on-module is designed to work with IEEE 802.15.4 and ZigBee WPAN communication protocols. The ZigBit module is compatible with a ZigBee stack that supports a self-healing, self-organizing mesh network, while optimizing network traffic and minimizing power consumption.

2.3.6 CC1350 SimpleLink™ Ultra-Low Power Dual Band Wireless Microcontroller

http://www.atmel.com/pt/br/devices/ATxmega256A3U-and-AT86RF233-ZigBit-Wireless-Module.aspx

---

The CC1350 is a member of the CC26xx and CC13xx family of cost-effective, ultra-low-power, 2.4-GHz and Sub-1 GHz RF devices from Texas Instruments™. Very low active RF and microcontroller (MCU) current consumption, in addition to flexible low-power modes, provide excellent battery lifetime and allow long-range operation on small coin-cell batteries and in energy-harvesting applications.

The CC1350 is the first device in the CC13xx and CC26xx family of cost-effective, ultra-low-power wireless MCUs capable of handling both Sub-1 GHz and 2.4-GHz RF frequencies. The CC1350 device combines a flexible, very low-power RF transceiver with a powerful 48-MHz ARM® Cortex®-M3 microcontroller in a platform supporting multiple physical layers and RF standards. A dedicated Radio Controller (Cortex®-M0) handles low-level RF protocol commands that are stored in ROM or RAM, thus ensuring ultra-low power and flexibility to handle both Sub-1 GHz protocols and 2.4 GHz protocols (for example Bluetooth® low energy). This enables the combination of a Sub-1 GHz communication solution that offers the best possible RF range together with a Bluetooth low energy smartphone connection that enables great user experience through a phone application. The Sub-1 GHz only device in this family is the CC1310.

2.4 Protocols and standards

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2.5 Communication KPI's

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

3 Development of Wireless Monitoring System

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

4 Results and Discussion

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

5 Conclusions and Future Work

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Attachment 1 — System Requirements Specification

System Requirements Specification (SRS)

PV wireless monitoring

Using this Document – System Integration Benefits
The System Requirements Specification (SRS) document describes all data, functional and behavioral requirements of the hardware and software under production or development.

Table of Contents

1. INTRODUCTION

This section presents an overview of the SRS to help the reader understand how the document is organized and how to read and interpret it. The System Requirements Specification (SRS) document describes all data, functional and behavioral requirements of the hardware and software.

Renewable Energy System development are inherent to the power electronics development. In the scope of the microgeneration project of SYSTEC-ENERGY Research Unit – Smart Energy Systems and Technologies – a distributed PV harvesting with multiple power converters is in development. Despite of the standalone behavior of the PV power converters, a monitoring subsystem is expected to be implemented.

1.1. Purpose

The purpose of this document is to describe the specific requirements for the Wireless PV monitoring system. This document is intended to provide an unambiguous, concise, and complete list of requirements to help design the Gateway and the nodes attached to each PV power converter. This document will include constraints and show how to use the system.

1.2. Scope

The Wireless PV monitoring system is a system intended to acquire the data and behavior status of each PV power converter.

1.3. Context

Place the software in a business or product line context with the aim for the reader to understand the 'big picture'. Strategic issues relevant to context are discussed.

This work is inserted in the scope of a microgeneration project of the SYSTEC-ENERGY Research Unit. Figure 1 presents the main architecture of this project. Currently, several work has been done in this project to implement a monitoring subsystem. This work focuses on data collection from each power converter and also on its control by sending references and actions. At the moment of this proposal, no work has been done to implement the monitoring feature in the PV converters. This way, a wireless network implementation is proposed to monitor the PV power converters.

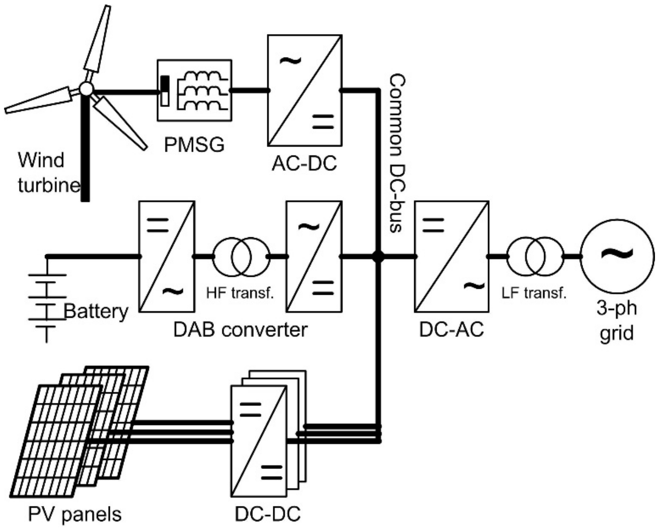

Figure 1 - Main architecture of microgeneration project.

The PV converter uses a non-isolated high gain DC/DC topology and has a PIC32 microcontroller which implements a MPPT algorithm in the control loop. It is currently possible to connect a device with wireless capabilities to the PV power converter. The converter is able to provide power and data. The data collected from the monitoring device is sent to an aggregator node for post processing and data storage. Currently, several work has already been done to have a reliable wired data aggregator/concentrator. This subsystem is also responsible for sending user commands to the power converters and presenting the user interface in a webpage remotely accessed via a web browser.

1.4. Organization

The rest of the document is broken down into seven sections.

Section 2 contains the overall description. In this section, the document will provide information about the system functions. Also included in this section is a description of the constraints needed for safety, as well as any assumptions made in the user characteristics and dependencies.

Section 3 has a hierarchical enumerated list of the requirements the system must fulfill.

Section 4 contains various models that specify the bridge between application domain and machine domain. In this section, UML diagrams and their respective detailed explanations are used to visualize and demonstrate the expected behavior of the system.

Section 5 gives an overview of the prototype, describes how to access it and run it, as well as examples of sample scenarios.

Section 6 gives a list of all the references used to compile this document.

Section 7 gives a point of contact if more information is required.

2. OVERALL DESCRIPTION

Present here a high-level overview of the product being specified and the environment in which it will be used, the anticipated users of the product, and the known constraints, assumptions, and dependencies.

The system to be developed is a wireless monitoring system capable of acquiring data from several PV converters, supporting the mechanical and EMI influences from the environment and being integrated to the current monitoring infrastructure.

2.1. Product perspective

Describe the context and origin of the product being specified in this SRS. For example, state whether this product is a follow-on member of a product family, a replacement for certain existing systems, or a new, self-contained product. If the SRS defines a component of a larger system, relate the requirements of the larger system to the functionality of this software and identify interfaces between the two. A simple diagram that shows the major components of the overall system, subsystem interconnections, and external interfaces can be helpful.

The wireless feature is intended to be added to the monitoring infrastructure supported in a System-on-Chip computer – namely a Raspberry Pi 2 – and the PV power converters.

The diagram in the following figure presents the overall perspective of the development expected by this SRS

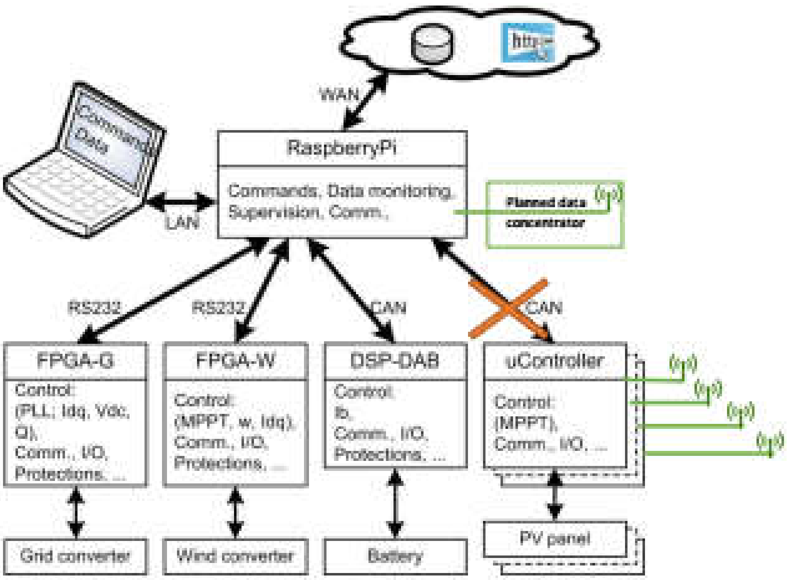

Figure 2 - Communication's architecture of microgeneration project.

The major requirements of the microgeneration monitoring system are the data acquisition and storage, having a website interface that might be easily accessed from the internet (with all the security constrains guaranteed). The relevant data must be identified, collected and transmitted using regular communication channels (RS232, SPI, CAN, etc).

2.2. Product features

Summarize the major features the product contains or the significant functions that it performs or lets the user perform. Details will be provided in Section 3, so only a high level summary is needed here. Organize the functions to make them understandable to any reader of the SRS. A picture of the major groups of related requirements and how they relate, such as a top level data flow diagram or a class diagram, is often effective.

This addition to the microgeneration project has two main objectives:

1. Extend the monitoring feature to the PV power converters
2. Implement and demonstrate a feasible wireless communication between the PV power converters and the head of the system

2.3. User classes and characteristics

Identify the various user classes that you anticipate will use this product. User classes may be differentiated based on frequency of use, subset of product functions used, technical expertise, security or privilege levels, educational level, or experience. Describe the pertinent characteristics of each user class. Certain requirements may pertain only to certain user classes. Distinguish the favored user classes from those who are less important to satisfy.

No user classes are expected in this communication module. The user interaction is defined by the upper layer of this system.

2.4. Operating environment

Describe the environment in which the software will operate, including the hardware platform, operating system and versions, and any other software components or applications with which it must peacefully coexist.

This system will be implemented in a cabinet with EMI constrains caused by the power converters. This SRS will include the specification of the hardware platform.

2.5. Design and implementation constraints

Describe any items or issues that will limit the options available to the developers. These might include: corporate or regulatory policies; hardware limitations (timing requirements, memory requirements); interfaces to other applications; specific technologies, tools, and databases to be used; parallel operations; language requirements; communications protocols; security considerations; design conventions or programming standards (for example, if the customer's organization will be responsible for maintaining the delivered software).

The wireless monitoring module to be placed in each PV converter should be attached mechanically and electrically. The figure 3 presents the PV power converter in question.

A design constraint concerns the space in the cabinet, where the PV power converters will be placed in a vertical orientation. The maximum space between boards must be no longer than 11cm (currently each board requires 8,5cm of free space). No extra space is allowed bigger than the PCB.

Figure 3 - PV power converter.

2.6. User documentation requirements

List the user documentation components (such as user manuals, on-line help, and tutorials) that will be delivered along with the software. Identify any known user documentation delivery formats or standards.

Complementary to this SRS document, a brief description of the hardware and software should be developed. This description will support the integration of this monitoring system onto the main system.

2.7. Assumptions and dependencies

List any assumed factors (as opposed to known facts) that could affect the requirements stated in the SRS. These could include third-party or commercial components that you plan to use, issues around the development or operating environment, or constraints. The project could be affected if these assumptions are incorrect, are not shared, or change.

Also identify any dependencies the project has on external factors, such as software components that you intend to reuse from another project, unless they are already documented elsewhere (for example, in the vision and scope document or the project plan).

It is expected that the final solution depends on software developed by the manufacturers for the wireless modules. No extensive analysis and code review is expected to be made upon that software.

2.8. Minimum system requirements

Describe the minimum system requirements for this product (e.g. platform version, disk space, RAM, etc.)

The minimum system requirements is not applicable due to the need for the final solution to select the platform and/or the hardware needed.

3. SPECIFIC REQUIREMENTS

3.1. Operations

3.1.1. The system must collect data from more than 1 PV converter (up to 10 PV converters)

3.1.2. Each wireless node should be powered by 5V

3.1.3. The wireless concentrator should be powered by USB (5V)

3.1.4. The system concentrator node must have an accessible broadcast mode that provides the received raw data from remote nodes.

3.2. Communication

3.2.1. Each wireless node should have a serial communication

3.2.2. The wireless concentrator should have a serial communication

3.2.3. The wireless concentrator should implement the microgen serial protocol

3.2.4. A wireless concentrator must collect data from all the nodes in less than 10 seg

3.2.5. All wireless nodes must send data to the wireless concentrator upon a request.

3.3. Safety/reliability

3.3.1. All data shall be sampled and hold upon a SYNC command.

4. DATA MODEL AND DESCRIPTION

This section presents various UML diagram to help showcase the functions of this PV wireless monitoring.

4.1. Use Case Diagram

A Use Case Diagram visually captures functions of the system. It shows the interactions between external actors on internal functions of the system. The system boundary helps to define the external actors and the internal functions. The extends signify another use case that is similar, with added functionality. Moreover, use case templates are provided to give detailed information for each use case of the system in the diagram. These templates show which actors are involved for a specific use case and shows the system requirement it satisfies.

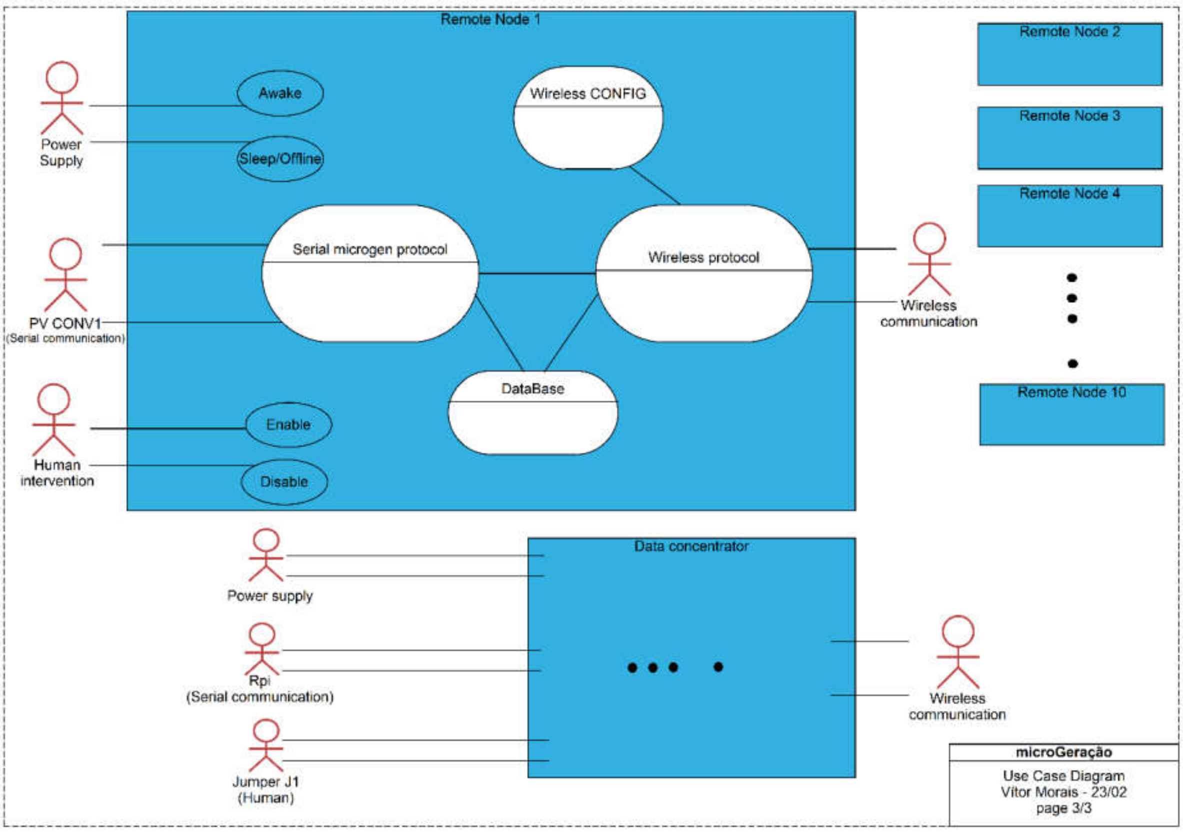

Figure 4 - Use Case Diagram – node

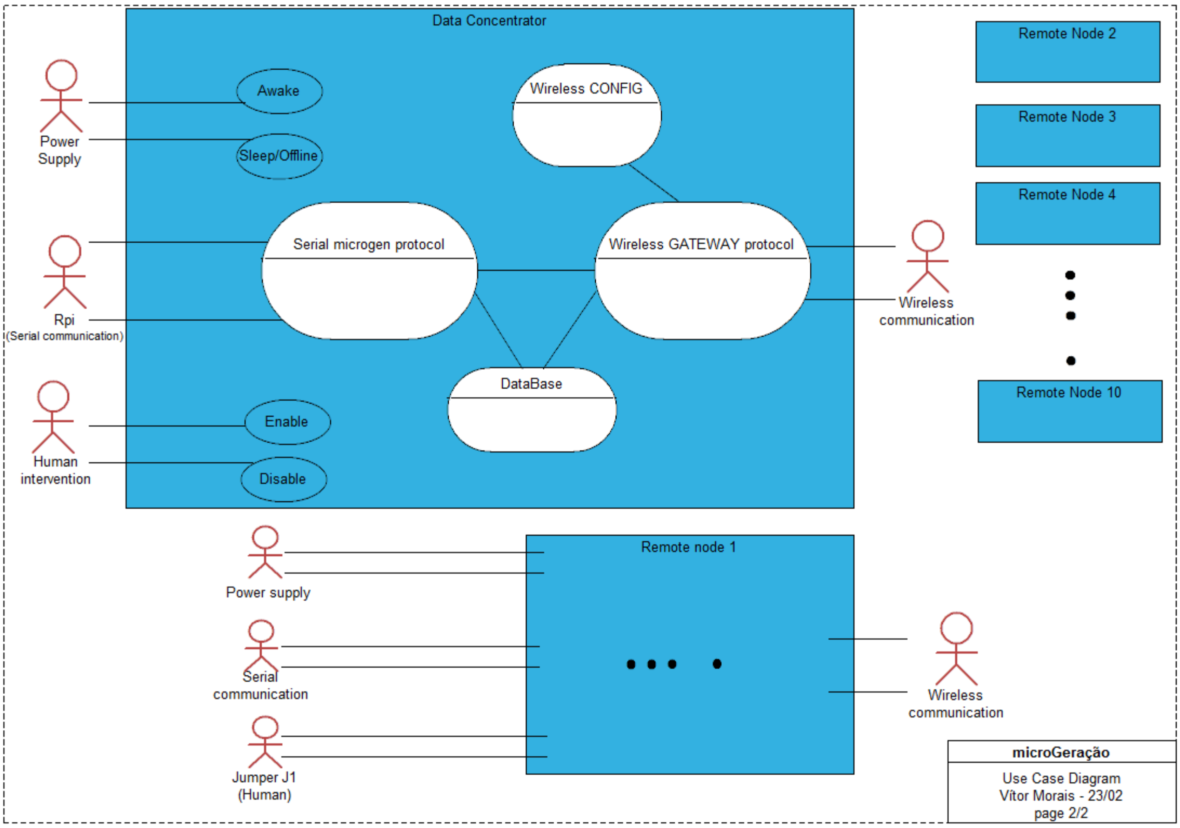

Figure 5 - Use Case Diagram - Data Concentrator

Use case	Awake
Actors	Power Supply
Description	The system should start up when the system voltage threshold is above 4.5 volts.
Type	Primary
Cross-Refs	
Use Cases	All

Use case	Sleep/Offline
Actors	Power Supply
Description	The system should go into sleep mode or offline mode when the system voltage threshold is below 3 volts.
Type	Primary
Cross-Refs	
Use Cases	All but awake

Use case	Enable
Actors	Human Intervention
Description	The system should restart and go to enable mode when the user presses a button (or jumper)
Type	Optional
Cross-Refs	
Use Cases	All but disable

Use case	Disable
Actors	Human Intervention
Description	The system should restart and go to disable mode when the user presses a button (or jumper)
Type	Optional
Cross-Refs	
Use Cases	All but enable

Use case	Serial microgen protocol
Actors	Rpi (serial communication)
Description	The system should execute the serial microgen protocol
Type	Essential
Cross-Refs	
Use Cases	All

Use case	DataBase
Actors	
Description	The system should stores the data and command between serial and wireless
Type	Essential
Cross-Refs	
Use Cases	All

Use case	Wireless CONFIG
Actors	
Description	The system should have stored all the configuration of remote nodes
Type	Primary
Cross-Refs	
Use Cases	All but disable

Use case	Wireless GATEWAY protocol
Actors	Wireless communication (with nodes)
Description	The system should send a SYNC signal to remote nodes; The system should receive all data from remote nodes
Type	Primary
Cross-Refs	
Use Cases	All but disable

Use case	Wireless protocol
Actors	Wireless communication (with concentrator)
Description	The node should broadcast all data to concentrator upon a SYNC command
Type	Primary
Cross-Refs	
Use Cases	All but disable

4.2. Domain Model

The following section contains a domain model and a data dictionary for the system.

In the domain model, boxes represent logical objects within the system. Within the boxes, lines preceded with a "-" represent individual pieces of information that that particular object knows, and lines preceded with a "+" indicate actions a given object can perform. Lines connecting the objects show relationships among the boxes, and include a descriptive name and numbers representing how many of each object is involved.

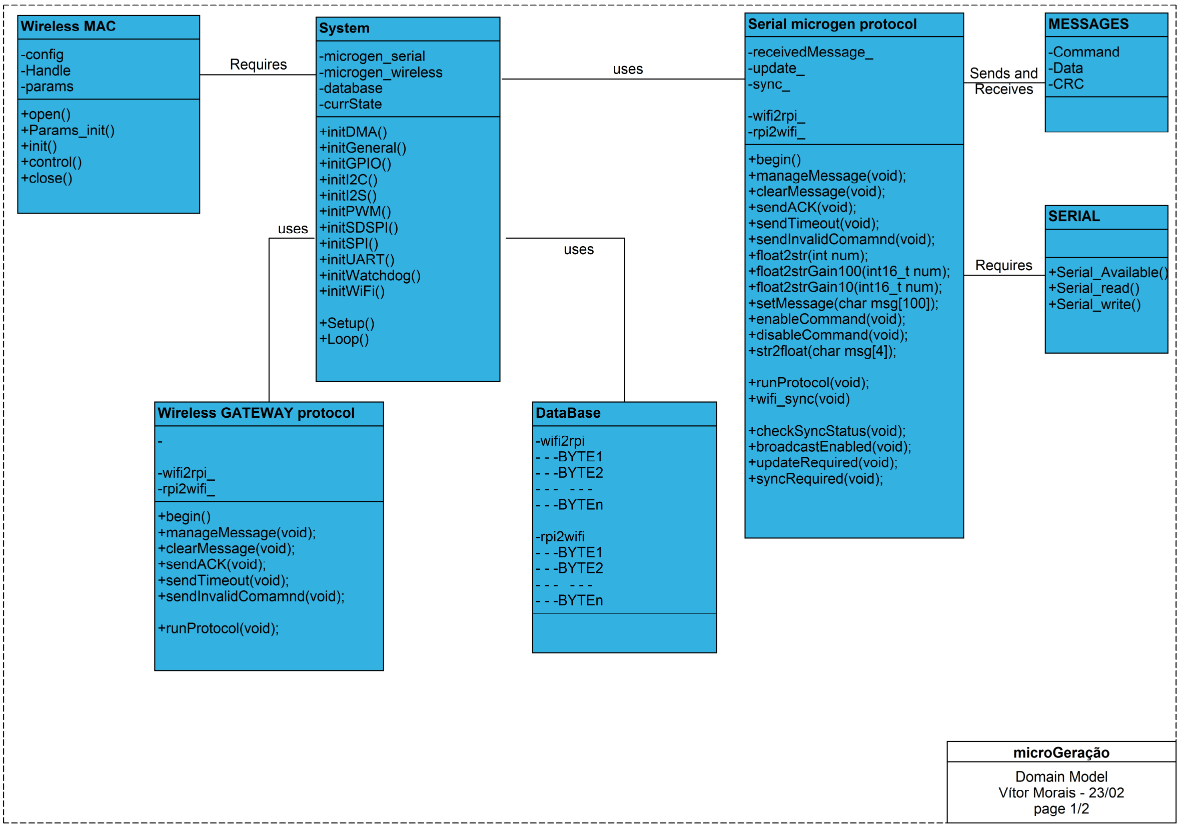

Figure 6 - Domain model diagram – Concentrator

Data dictionary

The data dictionary provides additional detail for every element in the domain model.

Element Name		Description
System		Contains the core functionality of the wireless concentrator node such as programming, protocol dependencies, peripheral and communication ports
Attributes		
	currState	Current state of the system: setup, loop_waitForSerial, loop_waitForWifi, loop_updateDB
	microgen_serial	Object of serial communication protocol between the data concentrator and the raspberry pi
	microgen_wireless	Object of wireless communication protocol between data concentrator and wifi nodes
	Database	Object of data storage
Operations		
	+initDMA()	Initialize board specific DMA settings
	+initGeneral()	This function initializes the general board specific settings.
	+initGPIO()	Initialize board specific GPIO settings

	+initI2C()	Initialize board specific I2C settings
	+initI2S()	Initialize board specific I2S settings
	+initPWM()	Initialize board specific PWM settings
	+initSDSPI()	Initialize board specific SDSPI settings
	+initSPI()	Initialize board specific SPI settings
	+initUART()	Initialize board specific UART settings
	+initWatchdog()	Initialize board specific Watchdog settings
	+initWiFi()	Initialize board specific WiFi settings
	+Setup()	General setup of the system
	+Loop()	General loop of the system

Element Name		**Description**
DataBase		Contains the data to be exchanged between serial and wireless
Attributes		
	wifi2rpi : struct	Data exchanged from wifi nodes to rpi
	rpi2wifi : struct	Data exchanged from rpi to wifi nodes
Operations		

Element Name		**Description**
SERIAL		Contains the serial Hardware layer (HAL)
Attributes		
Operations		
	Serial_Available()	Checks if serial read buffer is available
	Serial_read()	Reads incoming byte
	Serial_write()	Writes message to serial port
Element Name		**Description**
Serial microgen protocol		Contains the class description of the serial protocol implemented in the microgen project
Attributes		
	currState	Current state of the protocol: setup, run
	receivedMessage: array	Stores temporarily the received message
	update : boolean	Flag: if enabled then updates the database for the new data
	sync : boolean	Flag: if enabled then ask device for new messages
	wifi2rpi_	Database: stores the data received via wifi to be sent to rpi
	rpi2wifi_	Database: stores the data (commands) sent by rpi to the wifi
Attributes		
	begin()	Initializes the protocol
	+manageMessage(void);	Processes the received message
	+clearMessage(void);	Clears the received message
	+sendACK(void);	Sends via serial a ACK message
	+sendTimeout(void);	Sends via serial a TIMEOUT message

	+sendInvalidComamnd(void);	Sends via serial a INVALID message
	+float2str(int num);	Converts a number to ASCII and sends it via serial
	+float2strGain100(int16_t num);	Converts a number with 2 decimals to ASCII and sends it via serial
	+float2strGain10(int16_t num);	Converts a number with 1 decimals to ASCII and sends it via serial
	+setMessage(char msg[100]);	Sets message of receivedMessage array
	+enableCommand(void);	Sets command flag to COMMAND_ENA
	+disableCommand(void);	Sets command flag to COMMAND_DIS
	+str2float(char msg[4]);	Converts a received command value from ASCII to float
	+runProtocol(void);	Waits and receives serial message
	+wifi_sync(void)	Enables system for SYNC (or broadcast with remote nodes)
	+checkSyncStatus(void);	Disables Sync flag; returns SYNC flag status
	+broadcastEnabled(void);	Broadcasts all received raw data through the serial port
	+updateRequired(void);	Disables UPDATE flag; returns UPDATE flag status

Element Name		**Description**
Messages		Data structure of the exchanged serial messages: #DATA#CRC#
Attributes		
	Data	Data exchanged
	CRC	Number of bytes of DATA
	Command	Optional: it assumes the format {COMMANDVALUE} with 4 ASCII number bytes for COMMAND and 4 ASCII number bytes for data
Operations		

Element Name		**Description**
Wireless GATEWAY protocol		Contains the class description of the wireless protocol to be implemented
Attributes		
	currState	Current state of the protocol: setup, run
	wifi2rpi_	Database: stores the data received via wifi to be sent to rpi
	rpi2wifi_	Database: stores the data (commands) sent by rpi to the wifi
Attributes		
	begin()	Initializes the protocol
	+manageMessage(void);	Processes the received wifi message
	+clearMessage(void);	Clears the received message
	+sendACK(void);	Sends via wifi to a node a ACK message
	+sendTimeout(void);	Sends via wifi to a node a TIMEOUT message
	+sendInvalidComamnd(void);	Sends via wifi to a node a INVALID message
	+runProtocol(void);	Waits and receives serial message

Element Name		**Description**
Wireless MAC		Contains the wifi Hardware layer (HAL)
Attributes		
	config	Configuration parameters
	Handle	Object handler
	Params	Object parameters
Attributes		
	+open()	Function to initialize a given WiFi peripheral
	+Params_init()	Function to initialize the WiFi_Params structure to its defaults
	+init()	Function to initialize the WiFi module
	+control()	Function performs implementation specific features on a given WiFi_Handle.
	+close()	Function to close a WiFi peripheral specified by the WiFi handle

Remote node vs data concentrator

The code implemented in each remote node should be similar to the data concentrator. On the serial communication, the microgen protocol should be implemented in both the PV converter and the remote node. On the wifi communication, the remote node must implement a Medium Access Control similar based on a producer-consumer mesh network.

4.3. Sequence Diagrams

The following section contains the sequence diagrams. These diagrams pretends to evaluate the data exchange between the modules of the system. The diagrams are an hypothesis that may vary depending on the system architecture used and it is not binding.

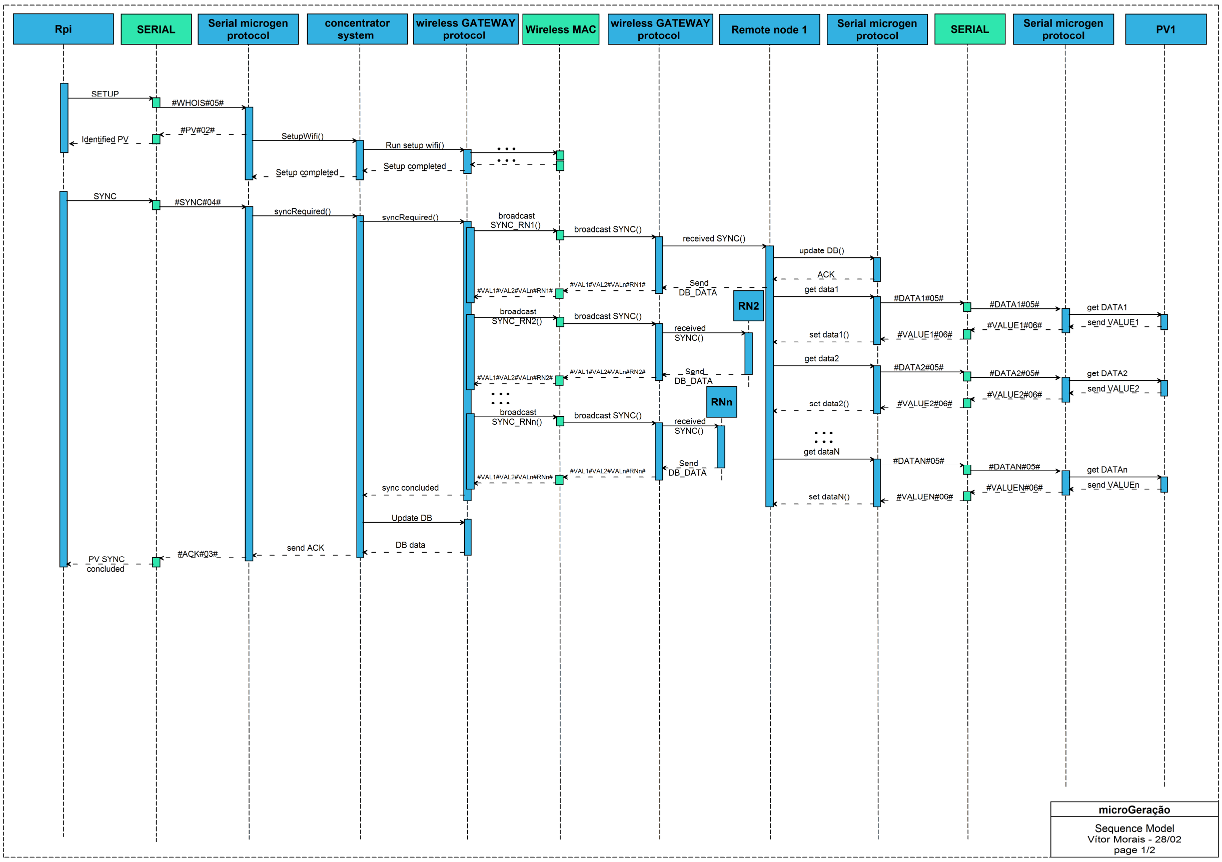

Figure 7 - Sequence diagram for SETUP and SYNC.

Figure 5 is intended to present the SETUP and SYNC sequences. Setup is a Raspberry routine intended to identify the devices connected itself. Sync routine provides a signal to all devices in order to hold the current variables in memory (dataBase). The signal SYNC must be broadcasted to devices at the same time, with a **maximum jitter of 10ms**.

The routine in the data concentrator device collects all data from remote nodes after a SYNC signal. The data collection from remote nodes should include the serial microgen protocol in both the remote node and the PV power converter.

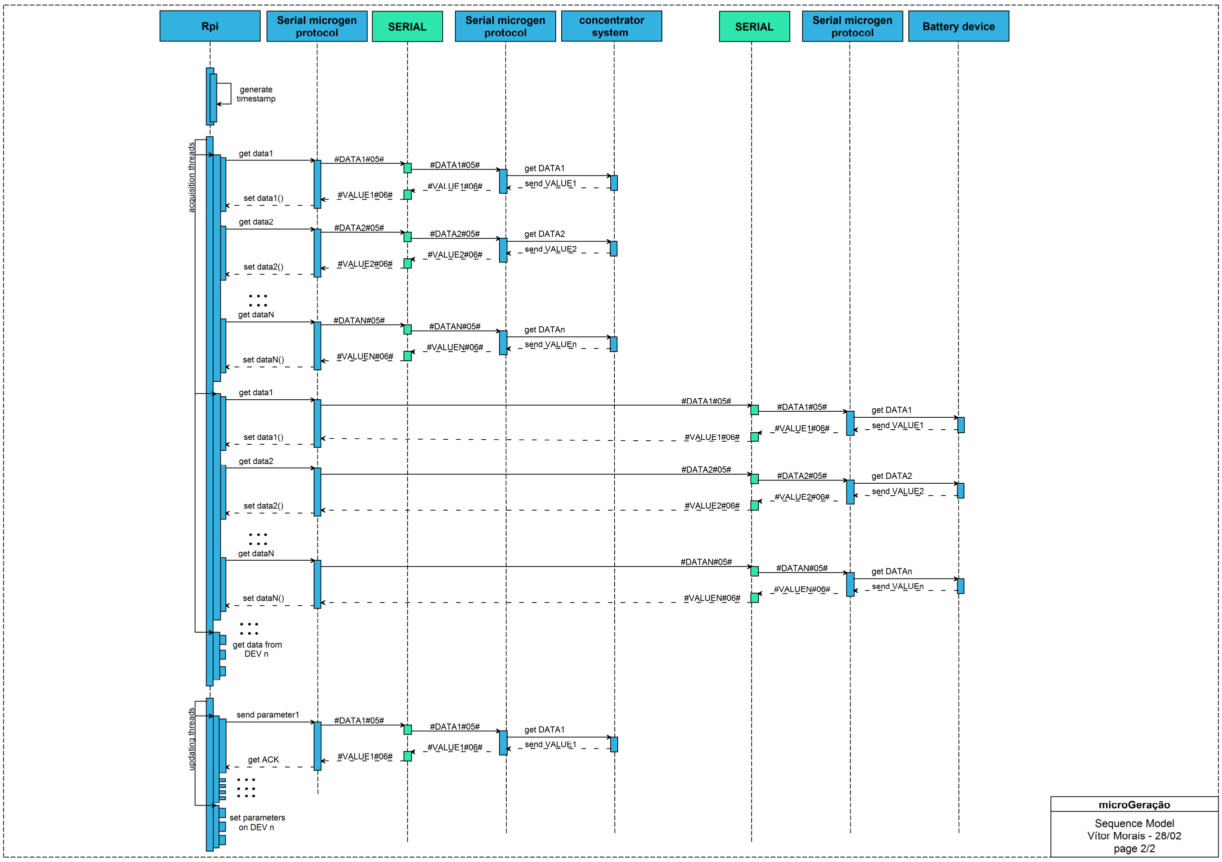

Figure 8 - Sequence diagram for timestamp, acquisition and updating.

After the last SYNC signal acknowledge received, the master should hold the current timestamp.

The acquisition of the data from each device should be processed simultaneously. From the point of view of the PV data concentrator device, all data should be transmitted using the serial microgen protocol.

The commands and references must be sent to devices after the acquisition. The same protocol should be used to send the data from the master to the data concentrator of the PV power converters.

4.4. State Diagram

The state diagram pretends to illustrate the possible states and transitions that may occur in the system. The proposed diagram may vary depending on the platform used and it is not binding.

The figure 7 shows all possible states and transitions for the PV wireless monitoring. States are marked using a round-edged box with a short description of the state. State transitions are signified using arrows with text descriptions. These descriptions generally consist of a function call and any constraints that need to be met before the transition is made. Constraints are indicated using brackets. The starting state of a diagram is indicated using a black dot pointing to a state.

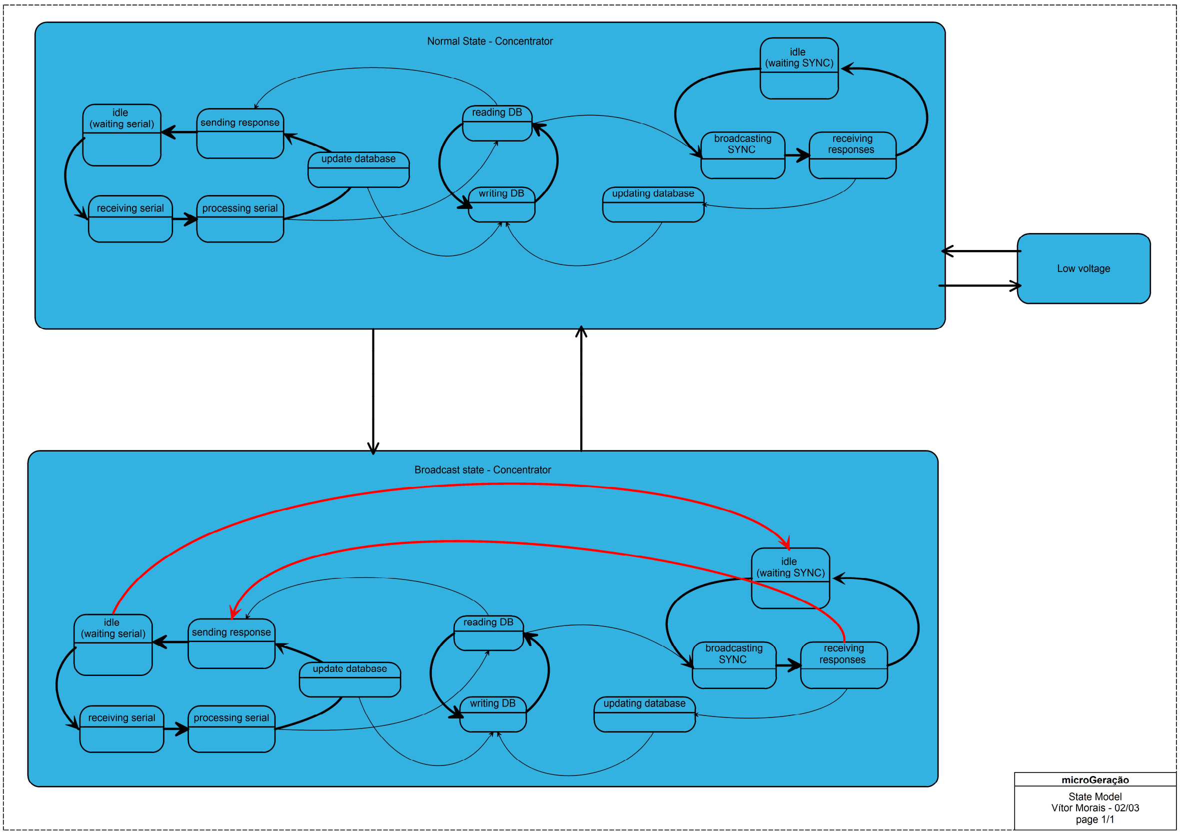

Figure 9 - State diagram for the PV wireless monitoring subsystem.

4.5. Prototype

The following section will describe the prototype behavior in different scenarios. The prototype may depend on the platform and the proposed prototype operations are not binding.

The prototype visually simulates what happens on the system in different scenarios.

Prototype Operation

The main result of the PV wireless monitoring subsystem is accessible with a browser through the raspberry pi master interface.

A alternative result will be the access to the remote node using other mean of data presentation such as the serial port or an LCD.

5. REFERENCES

- The template used for this SRS is based on Generic Ethernet Gateway (GWAY) from Chrysler Group LLC (available at http://www.cse.msu.edu/~cse435/Projects/F2013/Groups/GWAY/Docs/GWAY_SRS_V3.pdf)
- Please check microgen.fe.up.pt for more information on the project publications.