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Radio-Frequency communication in a SCADA system for the monitoring and control of intelligent building and office blocks

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Abstract

The efficient use of electricity and how people approach it, is a topic that has a big impact on the environment and society. The consumption management will be improved by the monitoring and the controlling of electrical installations. Communication is a key part in this process and that is why the improvement of data transmission is very important to obtain a controlled process. Transferring data is achieved by sending an electromagnetic signal by means of different types of communications channels. This paper presents a connection between a superior network and an external one to create the possibility of monitoring and controlling devices linked to the networks in a research institution (GECAD). The communication devices used are modems which use radio waves to make the transmission. A program has been created to access the data of an energy meter to obtain knowledge on how to implement analyzers in a SCADA system to improve monitoring of an electrical installation. This assignment will achieve a better understanding of the different protocols and operation modes.

Keywords: Intelligent building; SCADA system; MODBUS TCP/IP; ARM-SE; radio transmission

1. Introduction

In recent years the concern about energy consumption and its energy sources is growing since they may have environmental impacts. Renewable energy resources are a solution in order to overcome this barrier..

The buildings are one of the biggest energy consumers, somehow there is no efficient management on the use of energy. With increasing the population of communities, it is important to make buildings more efficient, and the use of smart devices and software that analyze several parameters, which allows a more reliable energy consumption management. This electrical system is known as a smart grid and uses the information of the installation to manage and improve energy consumption.

The industrial sector is important to integrate these intelligent systems. It is projected that in 2040 industry will consume more than half of the global delivered energy. Fossil fuels are still the biggest energy supply however the nuclear and renewable energy are growing fast. This means that the use of these energy sources has a big impact on the development of systems to control the energy consumption. As an example, solar panels contribute during the day but depend on the weather and other factors. This create an inconsistent source of energy that needs to be controlled and managed for an efficient use.

Besides of residential and commercial, the industrial and transportation sector are also major consumers. When talking about smart buildings it can easily be extended to smart cities on a larger scale. The smart grid is the base of the intelligent controlling of systems and actively managing of the consumption [1].

Connectivity and management are the pillars of the intelligent systems to reflect on the consumption in the different sectors. It is important to react where necessary to create an efficient consumption with an environmentally friendly focus. Intelligent algorithms are designed to access the information needed to manage the installation. These algorithms are created to be integrated easily in a process because they are flexible and can be wirelessly connected to an operating system. The use of a SCADA system make it possible to collect, process, display and manage information for the intelligent buildings.

The assignment is creating the ability to control and monitor an extern network to manage production and the consumption in the future using a new radio modem that GECAD has bought. The aim is to establish data transmission, creating a link between two separated networks and retrieve usable data. The focus is on the connectivity and creating an own SCADA system to monitor and manage an extern installation [2] [3].

There are many ways to achieve data communication to reach connectivity of intelligent buildings such as Ethernet, LAN, Wi-Fi, serial communication, etc. Avoiding hardwiring is often useful because of its substantial costs or when it is not geographically possible. But sometimes it is the cheapest way to create the communication.

Wireless communication has many advantages which are created by applying new techniques to improve the quality of the radio bridge. The first requirements are the transfer distance which has increased drastically over the years with decreasing probability of failure. Capacity and speed of the transfer are also important to send as much information as needed. Furthermore, the geographic aspect and the costs of an installation are also influential aspects. The combination of all these factors is determining for the type of communication channel fits best for a specific data transfer.
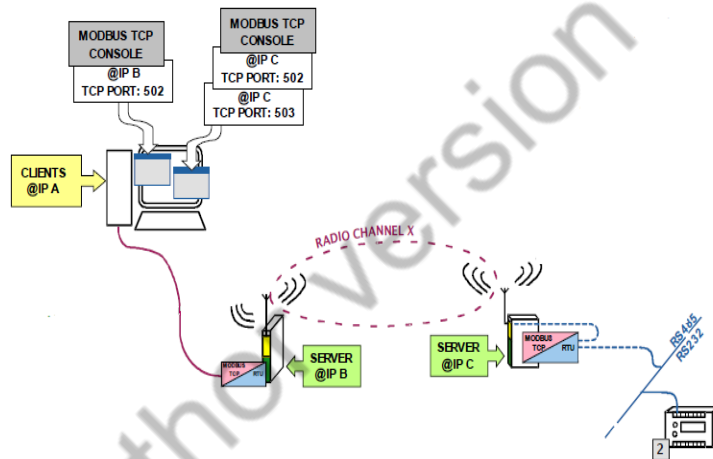
2. System Implementation

This chapter contains all the information about the equipment and the implemented system used during this assignment. The equipment and the topics that have been used in this system are:

- *ARM-SE* – The ARM, (Advanced Radio Modem), using a license-free high-frequency band located between 863MHz and 870MHz, suitable for industrial, medical and scientific applications. ARM-SE can operate with serial ports RS232 and RS485 or Ethernet as an alternative of Wi-Fi as the communicator with the network. The largest power is around 500mW which can reach over 5 km of range [4].
- *ANT868-BZ* – The antenna used in the test set up which is an omnidirectional antenna, especially designed for mast fitting.
- *PM130 PLUS Power Meter* - The PLC is connected to 3 PM130 PLUS energy meter for monitoring real-time energy consumption.
- *SCADA System* - Abbreviation of Supervisory Control And Data Acquisition (SCADA) is a system that is integrated into the industrial sector because it creates an easy visualization and exchange of data for an operator. SCADA communicates with Ethernet RS232 or RS485 and the software, downloadable from the site has a customizable interface which can operate a machine by writing data to the control unit. In this system, several PLC have been used in order to implement the SCADA system.
- *MATLAB* – This software is used by GECAD to retrieve data through Modbus. The system that serves as the SCADA system for this assignment can be reproduced as a program developed in MATLAB®.
- *Modbus* - The protocol has become a common tool for transmission between various kinds of electrical devices. Modbus protocol operates between a client and a server however it can also be interpreted as master and slave. The client and master have the same function as server and slave for Modbus which can create confusion.
- *Modbus TCP/IP* - TCP stands for Transmission Control Protocol while IP stands for Internet Protocol. Modbus TCP/IP is just an RTU command with an Ethernet TCP/IP wrapper. A Modbus TCP/IP frame fabricated for a transaction is called the ADU, (Application Data Unit), which exists in two parts: the protocol data unit and the Modbus application header. Both parts create the message for the transaction.
- *Modbus RTU* - The similarity with the TCP frame is obvious but the differences are the 1 byte slave ID in front of the frame and the two bytes CRC at the back. The slave ID is to identify the slave so it needs to be the same value as the ID of the slave [5] [6].

A connection between two or more modems can be achieved by two main configurations, which are both described below. During this assignment, both configurations were tested but the accentuation is on the principle that allows a larger number of devices to communicate. There are only two modems available to test these principles but it can be enlarged to communicate between lots of different industrial devices [7].

- *Point to Point (P2P)* - This configuration is the simplest way to communicate between the modems because the data just has to go from one point to another. There are no other devices and modems involved besides the two original modems.
- *Point to multipoint* - The 'point to multipoint' configuration is split between two main functionalities, the access point and the clients. The Access point can interact with each client, together or separately, while the clients can't communicate with each other. This principle is used to monitor different devices on one network which can be used in the industrial sector. In this assignment, there is only one client given the lack of more modems but it still can be a presentation of reality when using more devices.
- *Alerts* - The webpages provide a system that can alert the person who uses the modem in case of emergency. The tab 'Alerts' gives the opportunity to detect an error and to warn the operator. Watchdogs are an integrated function that measures the time that no data are transferred to see if an error occurred. It also compares the number of bad packages compared to the total number of packages sent to analyze the quality of the signal during an operation. With the tab 'e-mailing' the status of the watchdog can be sent to an e-mail address when certain triggers are activated.

- Fig. 1: Diagram of the used operating system

The main focus of this paper is to implement a connection between two buildings, which enables the SCADA system to integrate the real-time data of another building in its information. The Figure 2 shows the flowchart of this process, including how the energy meters data reach to the SCADA network. The modems on the Modbus gateway operation ensure the communication with energy meters
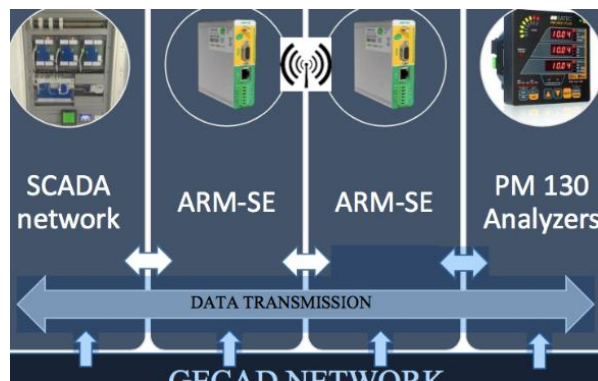

Fig. 2: Flowchart of SCADA process

Using this process, creates the possibility to monitor the energy meter in another building. The SCADA system will monitor all the necessary data by sending requests continuously. The response will be translated and monitored to control the installations.

The last step in the process is to access the data response trough a PLC in the GECAD laboratory with the computer to create the SCADA system. In the software of the PLC is shown which accesses the data and send it to a SCADA webpage, created by the PLC.

To create a link with the PM130 energy meter the request described in the previous paragraph needs to be transformed, despite the fact that both energy meter use the same protocol, the settings are different (e.g The messages send to the PLC are made out of 16 or 32 bits which is more than the 8 bit request of the energy meter).

Not only need the settings to be modified but also the amount of registers that will be accessed, are increased. Instead of collecting data from one register, this program needs to collect all of them and display them in graphs. This means the period and interval need to be chosen carefully to collect all the data so no error can occur. If there are too many requests in a small time-lapse the data will not be received anymore or it will lead to data corruption.

3. Case Study

The main aim of this report is to use the ARM-SE to integrate the data of an external building into the SCADA system in the GECAD laboratory. This means, creating a data transmission between the research lab and PM130 energy meter located in another building to monitor the installation. The energy meter are connected to a PLC and measure the electrical installation of the building. The modems want to retrieve that data to monitor the building. The PLC is situated in the F-building and can be reached using an antenna and the client modem. The most suitable modes and parameters have been selected in view of achieving the best transfer. First the created program in described in 0 is used to extract data of the power energy meter to check the quality of the transmission. Subsequently the energy meter is changed with the connection of the PM130 energy meter of the PLC to fulfil the assignment by collecting data of the electrical installation [8].

The research lab of GECAD is located in the N-building on the most southern point of the campus of ISEP. The access point modem is installed at this location. The PLC is located on the 4th floor of the F-building which is located next to the lab. At both locations, the modem and antenna are installed and tested to verify that a connection is possible. The only obstacles are the threes located between the two buildings that can hinder a transmission.

Before the actual installation the antennas are placed in both buildings and the test needs to be successful before it is possible to transmit data between the two locations. The test consists of a request to the client using the Modbus Gateway mode. If the access point receives the requested data, this indicates that the antennas are in the right place. As described before, the request and the corresponding response were generated successfully from the energy meter indicating a successful connection. This test is executed with the energy meter as this is the most efficient way to retrieve data.

The modem located in GECAD needs to be connected to the network to be accessible in the whole laboratory. In Figure 3 is a ground map of the two buildings and the antennas are also indicated with the symbol. It is noticeable that the trees can have an influence in the communication between the two modems.
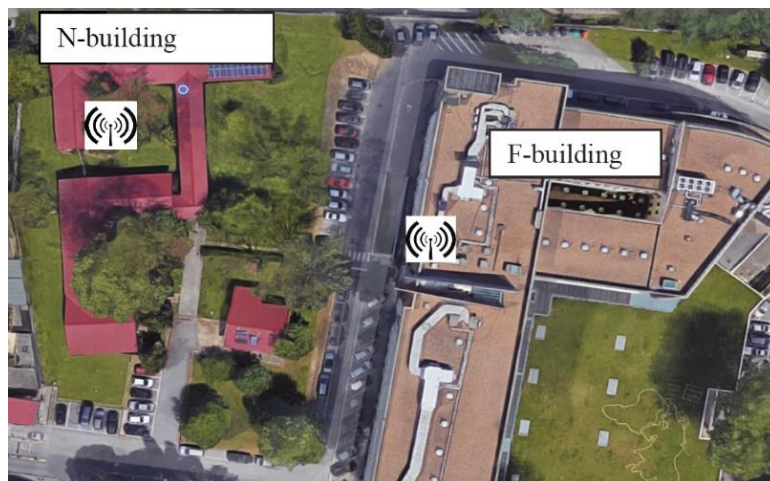

Fig. 3: Location of the antennas on map

The antenna is placed on the roof of the N-building and connected to the building using a cable. The modem will be installed on the wall and connected to the network of the GECAD-building to enable everyone to have access to the data by making the connection with the IP-address using the MATLAB® program.

The antenna of the client is attached close to the window to have a good reach while still being located close to the PLC. The modem itself will be installed next to the PLC to enable it to take power from the controller which is also 24V. The IP-address of this modem does not require corrections.

Modbus is a serial communications protocol which makes it compatible to communicate with the serial operation mode of the ARM-SE. The Modbus gateway is using the Ethernet cable while the serial operation mode uses RS485 or RS232. The PLC is compatible with the serial operation mode since the device has the Modbus protocol. This means that the energy meter can be connected to the RS485 of the client modem. The access point modem can run on the Modbus gateway operation mode which makes it accessible using the MATLAB® program. The reason for choosing Modbus TCP/IP and not Ethernet is the purpose of the design. Modbus is especially used to transmit data while Ethernet is used for other purposes. The Modbus TCP/IP protocol is used on an Ethernet layer but it can be found on other networks as well and can be used like a SCADA system, as mentioned before.

The energy meter can be connected to the modem which makes the choice for Modbus and serial obvious. There is a port available above the PLC with RS485 connection where the cables can be connected.

. After succeeding the connection with the power analyzer and successfully creating the graph, it is time to connect the modem to energy meter which are connected to the PLC. It is very important that the RS485 connection of the PLC itself is disconnected from the analyzers. Otherwise there are two different masters asking data of the analyzer, the PLC and the modem in GECAD through the client in the F-building. If this occurs the data cannot be transmitted to the modem which will indicate 'remote problems' on the webpages.

If one of the energy meter is connected with the modem independently of the PLC and the registers are known, a program is needed. Instead of using a new program, the data can directly be implemented in the SCADA system of GECAD to collect data of all the energy meter. Thereby the system can fluently extract data of energy meter over the antennas for a self-chosen amount of time and create a graphical form.

4. Results

After receiving the right data of energy meter, the data can be send to the self- created webpage of the PLC. It is shown below in Figure 4 how the voltages can be monitored. On the y-axis the values are between 2000 and 2600 but it needs to be divided by 10 to reach the exact value of the voltages.
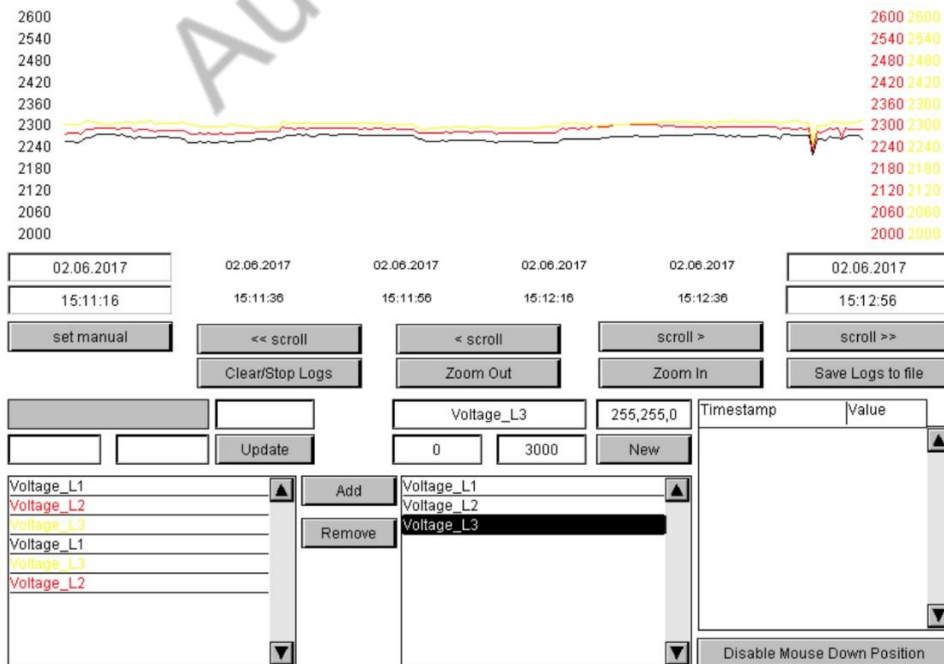

Fig. 4: SCADA webpage of the three phase voltages

This graphical form can be created with all the other registers of the energy meter. This shows the great purpose of a SCADA system that can access all the data and displays it clearly to make monitoring possible.

Other measurements cannot be displayed because, at the moment the analyzers only measure the voltage and frequency. The energy meter do not measure any current which indicates there is no consumption. When they are reconnected to the whole grid of the F-building the SCADA system will be able to display all the parameters of the installation.

The communication time between the SCADA system and the energy meter fluctuates between 500ms. This gives an indication that the radio waves can create a small distortion in the data transmission. This was also the case for the communication time of the CIRCUTOR but it does not create a big influence in the received data.

The response time between both modems is very fast which is perfect when integrating in a SCADA system.

In this case it is impossible to use this parameter to analyze the quality of the transmission because there were only two possible outcomes during this assignment. If the modems could communicate with each other, there were never packages lost.

All tests, were executed with a perfect signal where no packages were lost. But from time to time, it could occur that the signal got lost and no data could be retrieved

5. Conclusions

ATIM, the manufacturer of the ARM-SE modem, created a useful device to execute a data transmission using radio communication with different protocols. They managed to make the modem compatible with many operating systems and developed a system to create a fluent way for usage.

At the start of this assignment the modems were successfully configured and the different operation modes and protocols were tested. The tests of the various possible modes showed that there would be many complexities in the process. The first was to create an interface to display the response of any energy meter. This was only possible using the mode of the Modbus Gateway because it was integrated in the webpages. The interfaces for other operation modes were established using an Arduino, simply Modbus and Matlab®, which indicates the great variety of the modem. Ethernet was the only operation mode that was not tested with an external system because there were none available. The only way to test this mode was by using the command prompt on the computer for multiple Ping-Pong tests. The use of these different protocols in this research of the ARM-SE has shown all the possibilities of the modem. It created a clear view on how radio transmission and data transfers are realized.

All the various approaches to retrieve data between two modems, enabled to select the best way to connect the network of GECAD to energy meter of a PLC in an extern building. By connecting the networks energy meter a SCADA system can monitor the electrical installation. The energy meter used during the tests of the different operation modes can connect to the modem the same way an energy meter can be connected. This is why the MATLB® program was designed first for the energy meter so it became clear how to access the energy meter. The chosen operation modes for the modems have also been selected in function of the MATLAB® program and SCADA system. This means that the access point modem located in GECAD uses Modbus gateway and the client in the F-building uses the serial mode with RS485.

The program designed in MATLAB® can find the IP-address using the Modbus TCP/IP and generates a request in function of generating a response of the energy meter or PLC. These responses are recalculated and transformed into decimal values that in turn are displayed in a graphical form showing the fluctuation of the measurement over a specific period of time. When the energy meter were connected to the network of GECAD, the PLC could be configured easily because of the knowledge gained by the MATLAB® program. At the end of this assignment the SCADA system was able to reach the data of the PM 130 analyzers to monitor the electrical installation.

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